*The*
# ENGINEERS' DIGEST
REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XI No. 7. JULY, 1950

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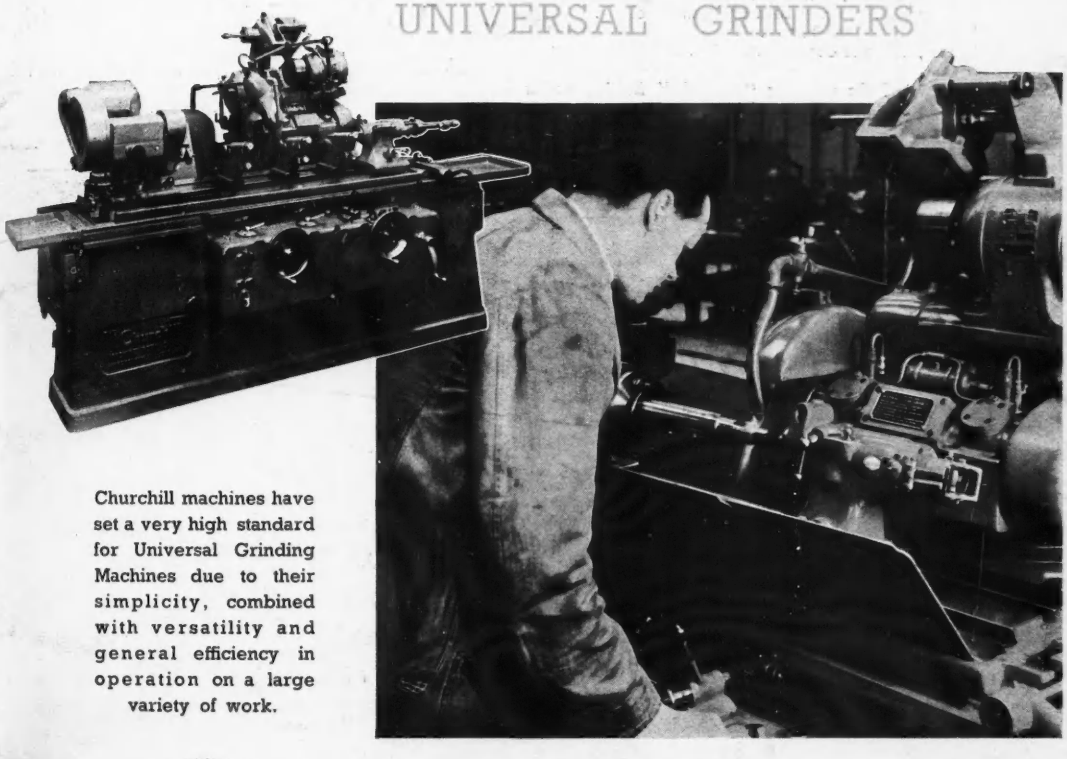

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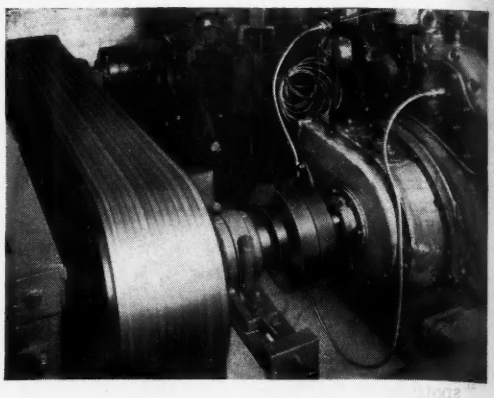

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# THE BLUE PAGES

## A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

### ● *ELECTROPLATING METAL POWDER PARTS*

There exist many cases where it is desirable to apply electroplating to the surface of component parts made of metal powder in order to improve their corrosion resistance or external appearance, as required. However, the surface porosity of such parts makes it difficult to obtain a uniform deposit of plating metal and completely to seal the surface by plating it. A still more serious problem is the internal corrosion caused by entrapped liquids or salts from the electrolyte, the corrosion working its way to the surface and erupting in a series of spots. This condition, which is known as "spotting-out," can now be eliminated by a new process, it is claimed. The process is based on the principle that the residual plating solution can be volatilized out of the pores by heat treatment. It appears that the process has been successfully employed for the electroplating of porous iron, brass and bronze parts, the coating materials including copper, nickel, silver, copper-nickel, copper-tin and chromium. Several modifications of the process have been evolved to meet specific requirements, and it is interesting to note that in one of these, the surface porosity required for subsequent oil impregnation can be retained.

### ● *REINFORCED BASIC FIRE BRICK*

A recently published British patent application by a firm of refractory manufacturers should be of interest to industrial furnace designers insofar as it describes an improved type of mineral fire brick for the lining of open hearth furnaces or other furnaces of the refractory basic type. According to this invention, basic mineral bricks are reinforced by steel in stiff openwork form, such as perforated or expanded plates, or woven, twisted or welded netting, extending over the length of the brick from face to back. This type of reinforcement is claimed to possess numerous advantages over the continuous steel sheet or tubing commonly used to face basic bricks. Among the advantages claimed is the feature that the mineral enters the perforations and thus remains securely keyed throughout the life of the brick. Also, the subdivision of the steel in small cross-sections throughout the lining is said to ensure rapid formation of a smooth glaze at the hot face of the lining—and this in addition to protecting the face against spalling during initial firing. The amount of steel provided in this form can, of course, be easily adjusted to the particular requirements of the type of basic mineral used in the lining, and it may also be varied over the length of the brick. External extensions of the steel reinforcement may be provided for the suspension of roof bricks, or holes in the metal may be arranged for the accommodation of suspension hangers.

### ● *ARCING BRUSH FOR CLEANING METAL SURFACES*

To facilitate the descaling of large metal surfaces, the Electric Welding Laboratory of the Soviet Ministry for Agricultural Machinery has developed a rotary wire brush driven by a motor and connected to one terminal of the secondary winding of a transformer. The other terminal is connected with the work-piece. Rotation of the brush, when in contact with the surface to be cleaned, results in the formation of numerous small arcs which burn away the scale layer, the burnt-off particles being removed by mechanical brushing action. In a prototype plant the brush was driven by a 2-kW motor at 2,800 rpm, the transformer supplying a current of 60-100 A. To ascertain the quality of surface produced by the process, spot welds were made on surfaces in the original and cleaned conditions respectively. It was found that the strength of the spot welds produced on the cleaned sheets was some 33 per cent higher as compared with the welds on the sheet in its original condition. The uniformity of weld strength was also found to be improved.

### ● *SELF-MAKING CEMENTED JOINTS*

Because of its bulk, wooden furniture of all descriptions in assembled state does not lend itself as readily to export as, for instance, steel office furniture, which can be shipped in knocked-down condition. A simple method enabling any unskilled person to make permanent joints between wooden parts by simply fitting matching parts together should, therefore, prove a considerable boon to the trade. According to a recent British invention, this problem is easily solved by placing a small breakable capsule filled with cold-setting synthetic resin cement in the cavity of the joint. By applying slight pressure to the parts to be joined, this capsule is broken and the plastic



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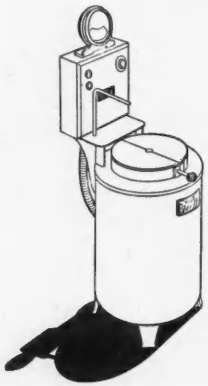

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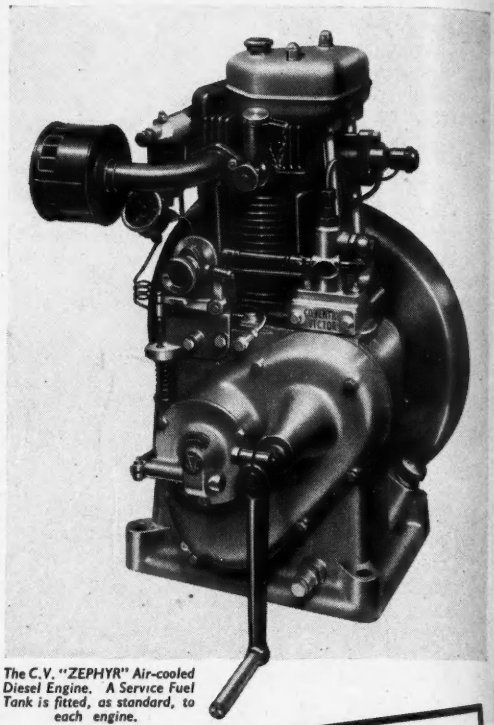

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cement is squeezed into the recesses of the joint, forming a permanent rigid bond upon setting. In order to prevent the joint from opening up while the bonding medium is setting, the joint may be designed to be of the self-locking type. Considering the great advances made in the field of bonding plastics in recent years, this proposal would appear to hold considerable promise, and plastic manufacturers would be well advised to give it their earnest consideration. The use of plastic cement capsules need not, of course, be restricted to joining wooden parts, and it is easy to visualise a great number of possible applications in other fields, such as the making of permanent joints between glass or metal parts, including fluid-tight joints in tubes and pipes.

### ● *MULTI-PURPOSE MOBILE DIESEL PLANT*

A German firm has commenced manufacture of a 32-hp diesel engine tractor incorporating unusual features, which should prove useful on construction jobs, especially in colonial development work. The engine is a two-cylinder four-stroke diesel; when the vehicle is stationary, one engine cylinder can be used as air compressor with the other cylinder driving it. The switch-over from straight diesel to diesel-compressor operation is claimed to be a simple operation which can be carried out while the engine is running. The free air capacity of the compressor is given as 56·5 cfpm, the delivery pressure being 85 psig. This compressor may be used for the operation of all kinds of compressed air tools and sand blast plant, paint spraying, etc. The engine is coupled with a welding generator of 9 kW capacity, allowing a wide range of welding operations to be performed. Even oxy-arc cutting is provided for, two oxygen cylinders forming part of the equipment. The welding generator may also be used for purposes of illumination, and up to fifty 100-W lamps can be supplied with current at 60 V without flicker. When required, an engine-driven winch for lifting as well as for the exertion of horizontal pull can be added to the equipment of this remarkable vehicle.

### ● *MEMORY SYSTEMS*

The complexity of operations to be performed by computing and analysing machines to serve a variety of purposes has led to the development of a number of memory systems based on various principles. One such system, according to a recent report, relies on the use of magnetic tape for the storage of numbers in a computing machine. Another memory system, of a more unusual type, now claimed to be in course of development, employs electrostatic principles, the message to be remembered being stored as an electrostatic pattern of dot-circle combinations on the screen of a cathode-ray tube. Electrostatic charges are, of course, subject to rapid deterioration, but a way has been found to extend the period of storage to many hours by providing a system of regeneration. This system periodically examines and re-establishes the charges on the screen before the message has become "illegible"; in other words, a self-refreshing memory has been created. This system appears to be particularly suitable in the field of telecommunication and telecontrol. At the present juncture, it is too early to assess the eventual range of applications of a system of this nature, but it is interesting to note that its development is being actively pursued both in this country and in the U.S.A.

### ● *NEW FIRE FIGHTER'S SUIT*

In fire fighting and damage control operations, there is a great need for a protective garment which will enable the wearer to enter flame- or steam-filled atmospheres to perform immediate rescue or salvage operations before extinguishing the fire or repairing the damage by conventional means. The U.S. Bureau of Ships, in recognition of the usefulness of such a protective garment, has developed a suit which allows the wearer to enter and remain in the flames of a petrol fire for some three minutes, the temperature in the suit not rising above 130° F with a flame temperature of 2,000° F. In confined spaces resembling the engine room of a ship, heated to 185° F and filled with steam, the wearers of the new suit could remain for 10 minutes without experiencing discomfort. The combination of fabrics selected for the suit consists of an outer cover of either glass or asbestos cloth, a layer of one-inch fibre glass insulation, a vapour barrier of lightweight neoprene-coated glass fabric, a second layer of one-inch fibre glass insulation, and an inner lining of woollen flannel. No such suits are available commercially as yet, but there should be a considerable potential demand for protective garments of this type both in the industrial and military fields.

### ● *PLASTIC-EMBEDDED CIRCUITS*

It appears that American manufacturers of electronic equipment are taking a considerable interest in the technique of embedding entire circuits and component parts in rigid plastic materials. This technique is sometimes referred to as "casting" and consists in preparing a mould of appropriate dimensions, in which the parts to be embedded are placed, and then filling the mould with liquid resinous material. Subsequent polymerization then converts the resin into a rigid solid. Various embedding materials with excellent physical and electrical properties are available, and it is, for example, possible to employ essentially pure styrene, which is noted for its electrical properties. Other plastic materials can be made up to suit specific requirements.

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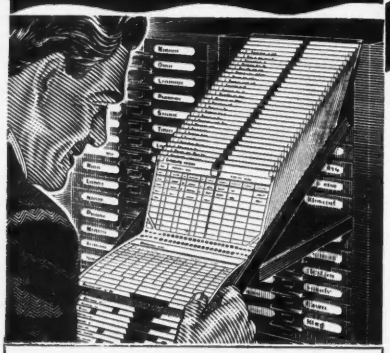

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Transparent as well as opaque substances are available and any colour can be produced. Obvious advantages of the embedding process are hermetic sealing, shockproof and rugged structure, elimination of mountings, use of bare point-to-point wiring for rapid circuit assembly, etc. High thermal conductivity for the effective dispersal of heat may be achieved by using fillers of high thermal conductivity, including metallic fillers. It is reported that at Massachussetts Institute of Technology this technique is being utilised in the development of complex electronic systems for guided missiles. In this application, hermetic sealing is of particular importance, as apparatus of this type must be capable of indefinite storage, but must give unfailing service when called upon.

### ● *REVOLVING MERCURY SHAFT SEAL*

Shaft seals of the kind used in various types of turbo-machinery serve to prevent the leakage of fluid from a high-pressure area to a lower-pressure area through the clearance existing between the revolving shaft and the stationary counterpart. In addition to the prime requisite of tightness, minimum friction and minimum wear of the rubbing surfaces are essential requirements. Recent studies of the problem of sealing the propeller shafts of ships have led to the development of a centrifugal mercury seal in combination with a rubbing seal, the latter ensuring fluid tightness while the shaft is at rest and until it has reached the speed required to establish the mercury seal by centrifugal action. In this design, the mercury is contained in an annular channel secured to the shaft with the flexible elements—made of rubber substance—of the rubbing seal forming part of this channel. Upon establishment of the mercury seal, the flexible elements are automatically lifted from the stationary member so that all rubbing contact is eliminated. Seals of this type may prove useful in compressors, pumps and perhaps also steam turbines. Care would, of course, have to be taken not to exceed the boiling temperature of mercury.

### ● *NEW RUSSIAN STEAM LORRY*

Although steam-driven lorries have now all but disappeared from the roads of this country, the inherent advantages of the steam drive—particularly the robustness of its mechanism—are still a recent memory. For Russian conditions, the possibility of firing steam lorry boilers with wood or whatever solid fuel is locally available should prove invaluable, particularly if the difficulties of ensuring petrol or diesel oil supplies in vast and sparsely populated regions are considered. Every feature of the new type of steam lorry now in production in the Soviet Union points to the endeavour of its designers to produce a vehicle capable of coping with the worst of roads under semi-arctic conditions, with the nearest repair shop some hundreds of miles away.

The Russian standard steam lorry model is designed for a useful load of six tons, the service weight loaded being 14·3 tons, including a wood fuel supply of 830 lb and a boiler water supply also of 830 lb. The service speed is given as 25 mph. The boiler is of the natural circulation water tube type operating at 350 psi pressure and 750 to 800° F steam temperature and producing steam at the rate of 1320 lb per hour. The vertical three-cylinder single-expansion engine is double-acting and develops 100 hp at 1250 rpm. The condenser fan is driven by an exhaust steam turbine running at 2500 to 4000 rpm and operating at 17 psi to 60 psi pressure according to the main engine load.

### ● *WATER JET STABILISATION OF SHIPS*

In view of the recent installation in a large British liner of a mechanically operated anti-roll stabiliser of the fin type, a French proposal—originally made in 1932 and now revived—to accomplish the same effect by hydraulic means is of especial interest. It is claimed that this system has proved its effectiveness in a 33-ft long scale model of a passenger liner which was tested off the French coast last year. This stabilising equipment consists of two pumps arranged in the engine room, one along each side of the hull. These pumps draw in water through intake pipes pointing forward and discharge through lateral openings in the hull, so arranged that heeling moments of the required magnitude are produced by appropriate water jet action. The pumps are kept running at constant speed, and the control of the pump discharges is effected by means of a specially devised combined hydrostatic and gyroscopic control gear. A particular and unique refinement of the control gear mechanism is claimed to be the feature that it is sensitive not only to the angle of roll and the speed of roll, but also to the rate of the roll.

### ● *ULTRASONIC BOILER SCALE SUPPRESSOR*

There have been many attempts made in the past to employ other means than chemical to prevent scale formation in boilers and similar apparatus. Thus, for instance, it has been proposed to prevent the consolidation of lime crystals into a layer of scale, by imparting ultrasonic vibrations to the boiler water. If the efficacy of this method is taken for granted, then its economic feasibility must naturally rest upon the availability of ultrasonic generator plant at fairly low cost, and this has hitherto not been the case. According to a report from Switzerland, an ultrasonic water treatment plant has been developed there which is of particularly simple design—and presumably correspondingly low in

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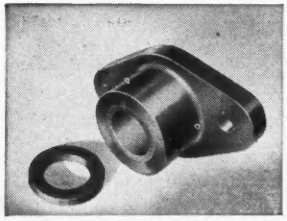

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cost. This apparatus incorporates a mercury switch alternately charging and discharging a condenser, the condenser discharge passing through the coil of the oscillator, which is in contact with the water to be treated. Energised by the discharges of the condenser, the ferro-magnetic core of this oscillator vibrates at the rate of some 27,000 cps. In view of the technical and economic importance of scale prevention, a thorough examination of this method would appear to be most opportune.

### ● *ELECTRODEPOSITION OF ALLOYS OF PHOSPHORUS WITH COBALT OR NICKEL*

A commercially applicable method for producing electrodeposits of cobalt or nickel alloyed with as much as 15 per cent phosphorus has been developed at the National Bureau of Standards, Washington. The new phosphorus alloys are more easily deposited than chromium and are very hard, corrosion-resistant and bright. They should, therefore, be of value for many of the applications where chromium plate is now used to obtain a hard wear-resistant surface, or a decorative finish. The appearance of the deposits depends upon their phosphorus content. Alloys with less than 2 per cent phosphorus are usually smooth with a matt finish; but as the percentage of phosphorus increases, they become brighter, reaching maximum brightness at a phosphorus content of about 10 per cent. Some of these alloys, when immersed momentarily in a solution of an oxidising agent, or made anodic in the plating bath, form a jet black film which is hard and adherent. The hardness increases with the phosphorus percentage and can be further increased by heat treatment. The ease of deposition, hardness, and corrosion resistance of the new alloys suggest the possibility of their application to gauges, cylinder walls, piston rings, and other parts where wear resistance is an important factor.

### ● *ULTRASONICS AS CAUSE OF SHIPBOARD FIRES*

Recognition of the fact that ultrasonic vibrations can be used to speed-up chemical reactions and to produce a number of physico-chemical effects has led to the development of an extremely interesting theory. According to this theory, ultrasonic vibrations produced by shipboard machinery may be the cause of shipboard explosions and fires. Among shipboard machinery, especially dynamos and winches have come under suspicion; and the fact that the latter are operative only in port, where outbreaks of fire and cargo explosions are particularly frequent, appears to contribute additional circumstantial evidence. Actual proof of the presence of ultrasonic vibrations was secured in the case of an American freighter which had suffered damage by an explosion in a cargo hold while undergoing repairs at the port of Le Havre. In this case, it was found that with three dynamos running, vibrations of a frequency of 450 kilocycles per second occurred near the spot where the explosion had taken place. With one dynamo and one winch in operation, ultrasonic vibrations of a frequency of some 100,000 cycles per second were noted. Considerably stronger vibrations at a frequency of approximately one million cycles per second were found to exist with three winches running. The occurrence of ultrasonic vibrations on board ship is, therefore, proved beyond doubt; but additional evidence will still be required to prove that these vibrations can actually lead to the outbreak of fires and cargo explosions.

### ● *DUAL CIRCULATION STEAM GENERATOR*

Shortly before the war, Russian technical journals reported the development of a boiler of the dual circulation type, in which different concentration ratios were maintained in the two systems. This development, which is based upon the proposals of E. I. Romm, appears to have made considerable headway in Russia during recent years. The dual circulation boiler as introduced into American practice consists of two separate heat-absorbing sections, each of which possesses its own independent circulation system. The feedwater enters the primary high-duty radiant heat absorbing section, which is continuously blown down to the low-duty secondary section, and since the blowdown from the primary section is large compared with the steam output of the unit, a low boiler water concentration may be maintained in the primary highly heated furnace tubes, while maintaining a much higher concentration in the moderately heated tubes of the secondary section. The most important advantage of the dual circulation boiler is the marked reduction in the amount of silica carry-over which may be realized. Since the concentration in the primary section where most of the steam is generated is low, the amount of silica vaporised may be expected to be low. The steam released in the secondary section, which is made from the highly concentrated boiler water, will have a much higher silica concentration, but, on the other hand, since the steam generated in the secondary section is small compared with the total boiler output, the amount of silica added by the steam from the secondary section will be small and the effect on the total silica leaving the boiler will be correspondingly small.

***For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.***



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Illustration of Borg and Beck Clutch.
*By courtesy of S. Russell and Sons, Ltd.*

# They expect a lot . . .

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# The Internal Combustion Engine Industry

THE Productivity Team from the British Internal Combustion Engine Industry, which was engaged on a mission of inquiry in the U.S.A. last October and November, under arrangements made by the Anglo-American Council on Productivity and the Economic Co-operation Administration, published its Report on June 8th. The Report points to important differences between the markets supplied by the industries of the two countries, and the effects these differences have on industrial techniques and output. It recognises the very considerably higher productivity attained in the U.S.A. and examines the underlying reasons. It makes a number of important recommendations, which include a revision of the wage structure of the industry, the application of time-study as a means towards efficient labour utilisation and protection for the worker, the payment of the rate for the job, and the reconsideration of the apprenticeship system and all that this implies to a skilled trade.

There is criticism of the availability of machine tools, particularly high-production and special-purpose machines, and the Report suggests that the effects on this country of exporting a high proportion of the output of the machine tool industry should be examined. Should the machine tool industry be expanded? Again, considering that there is a " bottle neck " in the supply of solid steel forged crank-shafts for larger engines, the Report asks how far the acquisition and control of a suitable forging plant by the Internal Combustion Engine Industry would help to overcome the difficulty.

Other recommendations concern technical methods, financial incentives to producers, the mechanical handling of materials, the training of supervisory staff, the interchange of information on production methods, and the examination of all practices which hamper output.

The British internal combustion engine industry is an important exporting industry; 90 per cent of its production goes abroad. In the U.S.A., 90 per cent of the industry's output is for consumption at home. The requirements of the American home market include variations of type and specification, but nevertheless users' demands enable batch quantities of engines to be larger than would be economical in Britain. Demand is also more predictable in America. In most cases, the works visited in America had surplus machinery as a consequence of high tooling-up for war time production, and they can obtain new machine tools now within a very short time. In this country, the machine tool industry, because of its export target, is sending abroad more than one-third of its total output and can only quote long forward delivery dates. In America, standard machine tools can be had within thirty days and specials within six months. In Britain, the diesel engine manufacturers have to wait from eighteen months to three years.

Labour utilisation was found to be better in the U.S.A. than in Britain. There was acceptance of non-craftsmen by management and the unions, except in such departments as plant maintenance, research, and the tool room. The emphasis in American plants appeared to be far more on the utilisation of each individual's time during his hours of work than on the total output of the plant, which, it is presumed, will be accomplished according to plan, providing the scheduling is correct and the individual time utilised by all is according to programme. It is essential that everyone in the country should clearly understand the benefits that are to be gained from high productivity, and the resultant position of the country if productivity is not raised. There have been many references to this in the Press and in Government publications and pamphlets, but many still fear that higher productivity might result in unemployment, and the fact that higher productivity will provide a higher standard of life, with more goods within the reach of more people, is even yet not understood by all.

It must be remembered that progress will continue, and better methods will be tried out and carried into effect by one nation or another. The country not keeping pace with the times will go under, and the standard of living will gradually fall to starvation level, particularly if that country has to import the major portion of its food.

It is therefore necessary that the fundamental principles of higher productivity should be stressed on every possible occasion by all with a sense of duty to their country, to their factory, to their community and to themselves.



XUM

# Current Design Practices for Gas Turbine Power Elements

By H. D. EMMERT. (From *Transactions of the ASME*, Vol. 72, No. 2, February, 1950, pp. 189-200, 21 illustrations.)

*This is the second instalment of an article discussing certain principles of design and analysis for power elements of commercial gas turbine plants. Whilst in our June issue the design of the turbine blade path was dealt with from the standpoint of fluid mechanics, problems under discussion here relate to the basic principles of stress analysis used for the blades and blade-carrying elements.*

## TURBINE-BLADE DESIGN

*Standard Blade Profiles.* A number of commercial gas turbines have been built utilising standard blade profiles of various types. These machines have given excellent performance within their normal ranges of application. The general trend, however, has been toward higher rotative speeds. Ratios of blade length to mean diameter are of necessity increased in such machines, and considerations of both three-dimensional flow effects and blade stresses have led to the general adoption of blades with warped surfaces and high degrees of taper.

*Basic Profile-Design Principles.* The significant dimensions and angles used to control profile design are illustrated in Fig. 7. The most important parameter is the opening coefficient, which is defined as the ratio of the minimum passage width or throat opening between adjacent blades to the circumferential pitch of the blades. Control of both fluid efflux angle and mass flow is exerted primarily by means of the opening coefficient. As long ago as 1924, the fluid angle was given quite closely by arcsine $(O/P)$. Subsequent tests have verified this approximate relationship within a reasonable range. General experience indicates that the curve in Fig. 8 provides a relatively accurate guide. The curve shows an increasing deviation of the fluid angle from arcsine $(O/P)$ as the opening coefficient is increased.

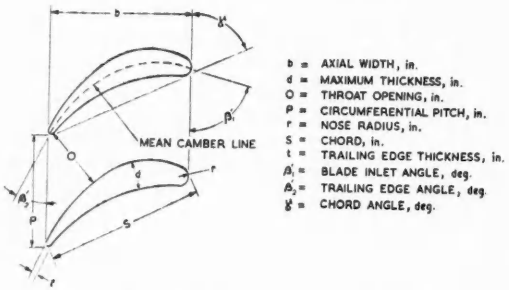



Fig. 7. **Profile and blade-ring nomenclature.**

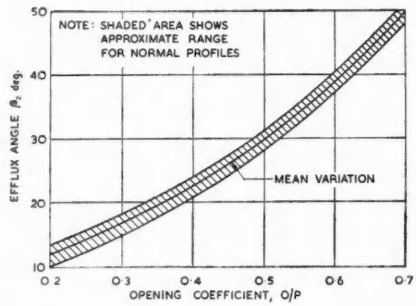



Fig. 8. **Variation of efflux angle with opening coefficient.**

Blading performance is affected to a large extent by the aerodynamic loading on the profiles. The resultant force acting on a profile corresponds to the integrated pressure differences between the convex and concave surfaces. In closely pitched blades, these pressure differences and their accompanying turbulence losses are reduced. However, losses due to surface friction are increased. Wide pitching decreases surface-friction loss, but aerodynamic loading is increased. This may induce stalling with an accompanying rapid drop in performance.

Aerodynamic loading is a function of the cascade solidity or chord/pitch ratio. The permissible ranges of blading solidity for standard profiles have been fairly accurately established by test. Complete correlation of test results has not been attained for all types of profiles, but sufficient data to permit interpolation between known optimum settings have been assembled and interpreted in terms of an aerodynamic loading coefficient.

For the practical design of a blade, vector diagrams at control points along the blade height are established from the data in the previous sections. The requirements for fixed blade-rings are generally such that normal reaction profiles can be used. The contours, pitches, and settings at all radii are established from experience with such configurations. The vector diagrams for long moving blades require that the profiles be varied along the radius. The fluid deflection angle at the blade base is generally large, and highly cambered, closely pitched profiles must be used. Depending upon the stress conditions and the root design, a ratio of circumferential pitch to axial width of from 0·45 to 0·60 is ordinarily selected. The profile at the tip is normally designed as a low-camber aerofoil of medium thickness. The aerodynamic loading coefficient is brought into use here, the solidity being established such that the loading coefficient does not exceed a permissible maximum value.

*Blade Layout.* Required blade pitches, throat openings, and axial widths or chords are established by application of the principles described in the previous paragraphs. Profiles are then laid out with the following considerations for guidance :

1. The stress in a blade due to centrifugal force is proportional to the blade volume above the point of stress. Profile thicknesses and cross-sectional areas must, therefore, be closely controlled within limits prescribed by preliminary stress analysis.

2. Geometric inlet and outlet angles are set at approximately the desired fluid angles. Exact correspondence is not necessary. The selection of inlet angle varies with the partial-load performance requirements for the stage and turbine.

3. Profile nose design depends upon stress conditions and fluid velocities. Moderately small nose radii are ordinarily prescribed. Trailing-edge thicknesses are consistent with the particular manufacturing process to be used and vary from approximately 1 per cent of the chord to not over 8 per cent of the throat opening.

It is considered essential that the passage area between adjacent blades converge at all points in the direction of flow. The walls of the passage as formed by the blade surfaces are kept free of sharp changes in

radius of curvature. The actual contours of the profiles are described by combinations of either circular arcs or parabolic arcs, depending upon the desired degree and rate of change of curvature.

For ease in manufacture, it is usually desirable that the blade surfaces between the base and tip profiles be in the form of warped conical surfaces generated by a series of straight lines. Such a design greatly simplifies the die-making problem for forged and cast blades. It is essential when the blades are to be produced by standard machining processes.

## MATERIALS AND DESIGN STRESSES

*High-Temperature Materials.* Allowable working stresses in high-temperature portions of the blade path are based on rupture strength. Adequate 1000-hr stress-rupture data are available for nearly all materials considered applicable to commercial gas-turbine use. Consequently, little extrapolation of data is necessary for relatively short-service-life designs. Some uncertainty is generally involved for long-life turbines, but extrapolation is a relatively safe procedure as long as it is limited to approximately one logarithmic time cycle, and ductility can be predicted to remain sufficiently high. Materials which show a tendency toward brittle failure in long-time rupture tests are to be avoided.

At the present time, creep-rate and total-deformation data are seldom used for establishing actual working stresses for rotating parts. Stresses which are considered to be permissible from the standpoints of rupture strength and yield strength generally correspond to low values of total deformation. Such deformations are slow and steady in nature and are subject to determination by periodic inspection after a machine has been placed in operation.

Fatigue strength at operating temperature is of considerable importance in selecting blade materials. Compensation for inadequate fatigue data is obtained by keeping bending stresses low and controlling blade vibrational characteristics.

*Selection of Design Stresses.* The present state of knowledge concerning the effects of temperature on metals and the actual temperatures and stresses encountered by parts within a turbine, do not in most cases justify too complex a method of stress analysis. Discrepancies involved in using simple analyses adequately controlled by experience are less than the errors inherently present due to variations in properties of materials and to unpredictable stresses. These considerations make essential the use of moderate design stresses.

The important principles governing the choice of permissible working stresses are:

1. The machine must be protected against failure due to either fracture or excessive local deformations, under any anticipated load conditions.
2. Protection must be provided against unavoidable variations in properties of the materials as installed.
3. Some margin is essential due to inaccuracies in stress analysis.

Of the many types of stresses which are encountered in gas-turbine design, average stresses in tension, compression, shear, and bending are most easily determined. Therefore, they are used as the guiding criteria. Local high stresses due to stress raisers of various types are taken into account where necessary by stress-concentration factors. In many cases, such stresses are safely relieved by local yielding without failure, as a result of the plasticity of the material at operating temperature. Variable stresses are generally estimated from computed average bending stresses.

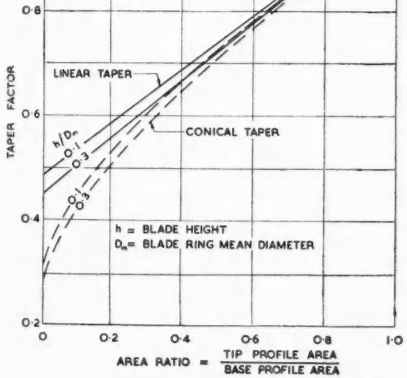



Fig. 9. **Variation of taper factor with blade-profile area ratio.**

## STRESS ANALYSIS

*Blade Stresses.* Blading stress analysis is concerned with a determination of the stresses set up by the centrifugal and bending forces generated by rotation and fluid pressure differences. The highest stresses encountered are almost invariably those resulting from centrifugal forces in the rotating parts. The tensile stress imposed on the base profile of a blade by centrifugal force can be calculated from the following formula

$$s_c = 4{\cdot}52\,\gamma f_t A \left(\frac{n}{1000}\right)^2 \quad \ldots \quad \ldots \quad (7)$$

where

$s_c$ = average tensile stress, psi
$\gamma$ = specific weight of blading material, lb per cu in.
$f_t$ = taper factor
$A$ = annular area of blade-ring, sq. in.
$n$ = rotative speed, rpm

The taper factor is unity for constant-cross-section blades and, assuming constant density of blading material, the stress becomes a function of only annular area and speed. Tapered blades are used where the installation of constant-section blades would result in excessive stresses. The amount of taper permitted in any particular blade is dependent upon the degree to which both flexural strength and efficient blade shape can be maintained. Fig. 9 shows the stress reduction which can be accomplished with various degrees and types of taper.

Basic bending stresses are generated by changes in gas velocity through the blades and by static pressure differences across the blades. Axial and tangential forces per unit length of blade are determined from the estimated flow conditions in the stage. Integration of these forces yields total component loads from which are determined the moments acting on any given profile of the blade.

The maximum stress in a blade is generally at the concave side of the leading edge of the base profile, since the stresses due to centrifugal force and gas bending force are additive in tension at this point. The total tensile stress resulting from centrifugal force and average bending force, therefore, constitutes the maximum steady stress in the blade. Variable stresses are expressed as percentages of the average bending stresses, and the effects of stress concentration are taken into account. The maximum stresses in moving blades are

$$s_a = s_c + s_b \quad .. \quad .. \quad .. \quad (8)$$

$$s_v = KR_v s_b \quad .. \quad .. \quad .. \quad (9)$$

where

$s_a$ = maximum steady stress, psi
$s_v$ = maximum variable stress, psi
$s_c$ = centrifugal stress, psi
$s_b$ = average bending stress, psi
$K$ = stress concentration factor
$R_v$ = ripple factor

Fillet radii and thickness ratios are such that the stress-concentration factor seldom exceeds 1·5. The ripple factor is a function of the blade pitches, flow conditions, and blade frequency, and it may reach values as high as 0·5 under adverse circumstances. It is somewhat lower with blade frequencies remote from those of possible exciting forces.

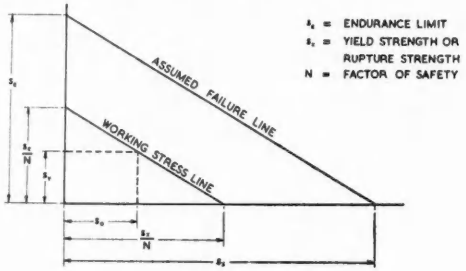



Fig. 10. **Assumed failure diagram.**

Stresses as determined by the foregoing formulae are compared analytically with an assumed failure line on either an endurance limit-yield strength diagram or an endurance limit-rupture strength diagram, as shown in Fig. 10. A minimum factor of safety of 2 is maintained for both comparisons. The actual stresses for use on the rupture-strength diagram are calculated at normal speed, and those for use on the yield-strength diagram are calculated at 120 per cent speed. This overspeed represents the maximum value for which commerical gas turbines are normally designed to withstand harmful permanent deformations.

*Blade-Frequency Analysis.* Accurate control of blade frequency is essential to ensure that vibratory stresses do not exceed the limits assumed in stress analysis. Normally, a new blade design is analysed and suitably modified so that the frequency corresponding to the first mode of transverse vibration lies above the fourth multiple of the maximum rotational speed. This rule has been found to be safe for gas turbines operating from combustion chambers attached by relatively long ducting. If necessary, a safe condition is assured by tuning the actual blading after installation.

The frequency of the fundamental mode of vibration of blades in a given ring is expressed by the following formula

$$f_s = 11{\cdot}0\, C_f \frac{k}{h^2} \sqrt{\frac{E}{\gamma}} \quad .. \quad .. \quad (10)$$

where

$f_s$ = standing frequency, cps
$C_f$ = frequency correction factor
$k$ = radius of gyration of base profile, in.
$h$ = blade length, in.
$E$ = modulus of elasticity, psi.
$\gamma$ = specific weight of material, lb per cu in.

For a value of unity for the frequency correction factor, the formula is identical to that for the frequency of a uniform cantilever beam of equivalent properties. The tie between theory and actual conditions is by means of the frequency correction factor. This factor takes into account blade-taper effects and, in addition, is dependent upon the actual geometric configuration, the type of blade fixing, and the presence or absence of shrouding and lacing wire.

Moving blades are stiffened to some extent by centrifugal force.

The running frequency is calculated from

$$f_r = \sqrt{f_s^2 + B\left(\frac{n}{60}\right)^2} \quad .. \quad .. \quad (11)$$

where

$f_r$ = running frequency at $n$, cps
$B$ = rotation coefficient
$n$ = rotational speed, rpm

The rotation coefficient is dependent upon the degree of blade-root fixing, the geometric shape, and the blade-height ratio. The effect of rotation is generally small, and it can be predicted with practical accuracy for normal constructions from the data in Fig. 11.

Blade vibrational characteristics are best depicted on a frequency diagram similar to that shown in Fig. 12. Safe operating speeds for the turbine may be estimated from such a chart with allowance for the effects of possible variations in blade frequency.

*Disk Design.* In practical design, elastic stresses are calculated in detail for blade-carrying elements mainly for the purpose of ensuring maximum utilisation of the weight of material put into the elements. For comparative purposes, however, the primary criterion is the average tangential stress across the disk's radial cross-section. This approach assumes, in effect, that the total centrifugal load due to the blades, rim, and

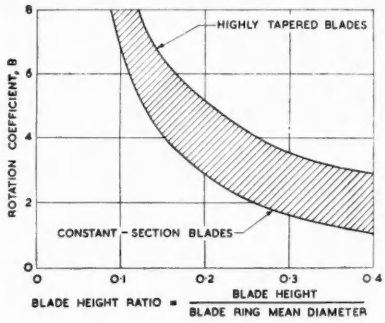

HIGHLY TAPERED BLADES
CONSTANT-SECTION BLADES
ROTATION COEFFICIENT, B
BLADE HEIGHT RATIO = BLADE HEIGHT / BLADE RING MEAN DIAMETER

Fig. 11. **Variation of rotation coefficient with blade-height ratio.**

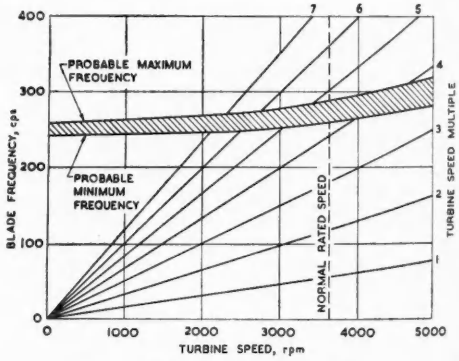



Fig. 12. **Typical blade-frequency diagram.**

disk proper is carried uniformly across the cross-sectional area of the disk. The formula for the average stress is expressed as follows:

$$s_{ta} = 28{\cdot}42\ \gamma \left(\frac{I}{A}\right)\left(\frac{n}{1000}\right)^2 + \frac{P}{2\pi A} \quad .. \quad (12)$$

where

$s_{ta}$ = average tangential stress, psi
$\gamma$ = specific weight of disk material, lb per cu in.
$I$ = moment of inertia of disk half section about axis of rotation, in.
$A$ = area of disk half section, sq. in.
$n$ = rotational speed, rpm
$P$ = total centrifugal force due to rim load at speed $n$, lb

Overspeed tests analysed in accordance with the conception of uniform stress distribution show much closer agreement between average tangential stress and test-bar tensile strength, than when the analysis is based on comparing local elastic stresses and test-bar strength. This is true for both solid and centre-bored disks.

Normally, disk stresses as calculated by means of eq. (12) are limited to one half the rupture strength of the material for the specified service life and temperature for the part, when operating at rated speed. Rupture strength becomes of minor importance at moderate temperatures. In such cases, the average tangential stress is limited to one half the yield strength of the material at the specified service temperature, when rotating at 120 per cent of rated speed.

Disk stresses may be reduced considerably if the disk outline is profiled. Calculation of local elastic stresses is helpful in attaining the optimum degree of profiling, and disks are designed with a constant-stress form where possible.

Stresses generated by thermal gradients may reach serious levels in units subjected to rapid load changes or where quick starting is required. Since these stresses are transient in nature, they induce results similar to fatigue. This phenomenon, which is known as thermal shock, may rapidly lead to failure if not properly taken into account in the design. Without going into particulars, such conditions are best combated by preventing undesirable temperature gradients as much as possible. In this respect, experience up to the present time with artificial cooling of parts subjected to hot gas has been somewhat disappointing. Induced temperature gradients in some cases have led to deformations and failures which would not normally have occurred, had the parts been permitted to assume more normal temperature distributions.

## CONCLUSION

There are many problems in gas-turbine design which cannot be discussed adequately in a presentation such as this. An attempt has been made, however, to show the approaches to some of the more basic problems peculiar to the design of commercial gas-turbine equipment. These approaches are simple and systematic in all cases and they are based primarily upon fundamental theory, modified by experiment and experience.

The gas turbine is in a state of development. This development must be based upon a background of basic data which can be accumulated only through experience. Since the commercial gas turbine is in direct competition with other well-established types of prime movers, the requirements for efficiency, dependability, and low first cost must all be given special consideration. The fulfilment of these requirements is greatly assisted by the organisation of fundamental principles and experience into basic design practices similar to those which have been outlined in this paper.

RUSSIA

# A New Infinitely Variable Friction Gear

By A. S. Darer. (From *Stanki i Instrument*, No. 2, 1950, pp. 3–6, 5 illustrations.)

*This new change-speed gearbox is claimed to be superior to existing variable gears of the frictional type, especially for giving a wider range of speeds than is generally obtained.*

### Principle of Ball Drive

The gear, shown diagrammatically in Fig. 1, consists of two cups facing each other, the driving cup (5) and the driven cup (2). Motion is transmitted by four balls (8), the axes of rotation of which can be tilted by means of four rollers (3). Each roller (shown as having a spherical surface in this drawing) revolves on a pin fixed diagonally inside a worm gear (4). The balls (8) are in continuous contact with the conically shaped surfaces at the rims of cups (5) and (2), the latter being pressed towards each other by coil springs via suitable thrust bearings.

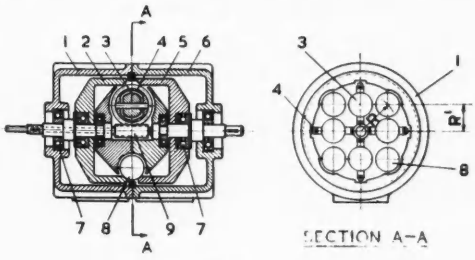



Fig. 1

As the driving cup (5) is rotated, it tends to rotate the balls (8). The axis around which each ball is free to rotate is, however, as already mentioned, determined by the position of the directing rollers (3). Hence, the circumferential velocity of the ball at the point of contact with cup (5) can be made to differ from its circumferential velocity at the point of contact with cup (2), and as—in the absence of slip—the circumferential velocity of the ball and cup at the point of contact must be identical, the circumferential velocity of cup (2) can be made to differ from that of cup (5).

To eliminate slip between cup and ball, it is necessary that the axis of rotation of each ball should lie in a plane through the axis of the cup (i.e., the main axis of the gear) and the point of contact between the cup and ball. The horizontal velocities of the cup and the ball at the point of contact will then have directions perpendicular to that plane, and will, in fact, coincide.

The gear has been so designed that the centres of the balls (8) form the corners of a square (see section A–A of Fig. 1). The points of contact between the balls (8) and rollers (3) lie on the sides of this square, and the sides of the square are formed by the axes of the worm gears (4) which carry the pins supporting

the rollers (3). This arrangement permits speed control with minimum effort during operation or at rest. The four worm gears (4) are rotated by means of the central worm (9), which they engage simultaneously.

### Basic Kinematic Relations

If there is no slip, and the circumferential velocities at the points of contact are identical,

$$\frac{v_1}{v_2} = \frac{r_1}{r_2} = \frac{n_1}{n_2} \quad .. \quad .. \quad (1)$$

where $v_1$ is the circumferential velocity of the ball and driving cup at the point of contact; $v_2$ is the circumferential velocity of the ball and driven cup at the point of contact; $r_1$ is the perpendicular distance from the rotating axis of the ball to the point of contact with the driving cup; $r_2$ is the perpendicular distance from the rotating axis of the ball to the point of contact with the driven cup; and $n_1$ and $n_2$ are the rotational speeds of the driving and driven cup, respectively.

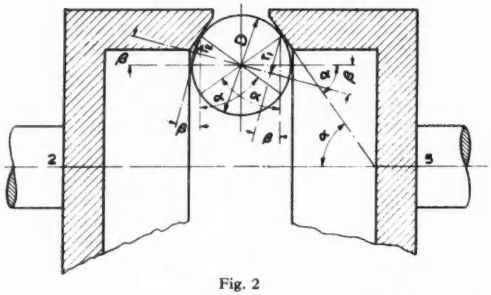



Fig. 2

In diagram Fig. 2, the relative positions are shown for the driving cup (5), the driven cup (2) and one ball, the axis of rotation of which includes angle $\beta$ with the main axis. It follows that:

$$r_1 = \frac{D}{2} \cos(\alpha - \beta) \quad .. \quad .. \quad (2)$$

$$r_2 = \frac{D}{2} \cos(\alpha + \beta) \quad .. \quad .. \quad (3)$$

where $D$ is the diameter of the ball and $\alpha$ one half of the included angle at the apex of the cone at the frictional surface of each cup.

$$\frac{n_1}{n_2} = \frac{r_1}{r_2} = \frac{\cos(\alpha - \beta)}{\cos(\alpha + \beta)} \quad .. \quad .. \quad (4)$$

If the axes of the grinding rollers are set parallel to the main axis of the gear, the balls rotate in parallel with them. Angle $\beta$ is zero, and from eq. (4), $n_1 = n_2$. As the central worm is rotated, the four worm gears in mesh with it revolve simultaneously. The axes of the four guide rollers each move in their respective planes, in every position intersecting the main gear axis at one common point. At the same time, the geometric axes of rotation of the four balls are also rotated. They also have a common point of intersection with the main gear axis. The design of the gear is such that for each angle $\beta$, these two common points of intersection of ball and roller axes coincide.

The geometric relations are illustrated in Fig. 3. Bearing in mind that the centres of the four balls form the corners of a square (see Fig. 1) and that the axes of the rollers pass through the centre of each of the four sides, a square-base pyramid is formed, the apex of which lies at point $O$ of Fig. 3. $AB$ and $BO$, the

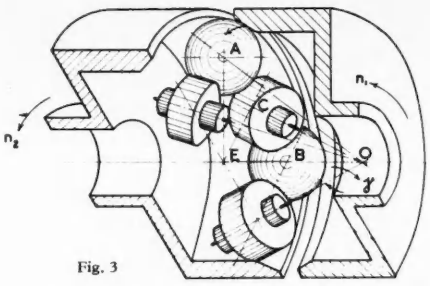



Fig. 3

axes of rotation of the two balls shown, are edges of this pyramid, whilst $CO$, the axis of one of the rollers, is the height of $ABO$, one of the lateral faces of the pyramid.

If $\gamma$ is the angle between $OC$ and the main gear axis $OE$, it can be shown that

$$\tan\beta = \sqrt{2}\tan\gamma$$

With this, equation (4) is transformed to

$$\frac{n_1}{n_2} = \frac{1 + \tan\alpha\tan\gamma\sqrt{2}}{1 - \tan\alpha\tan\gamma\sqrt{2}} \quad .. \quad (4a)$$

In the prototype model of the gear, the angle of the conical surfaces at the rim of each cup has been chosen as $\alpha = 35° 15'$. For this angle $\tan\alpha\sqrt{2} = 1$. With this, eq. (4a) is changed to

$$n_1/n_2 = \tan(45° + \gamma)$$

and if $\gamma$ is measured from the position of the roller axis when it intersects the main gear axis at an angle of 45°,

$$n_2 = + n_1 \tan\gamma$$

Thus, in theory, with a constant input speed, the output shaft can be made to rotate through the full range of speeds between $+\infty$ and $-\infty$. In practice, of course, experiments have shown that, to have a reasonable life, the gear must not be used for extremely high or low speeds. A maximum speed range of 10 to 12 is recommended. This is claimed to be considerably wider than the range of most other variable friction gear drives.

Fig. 4 shows a section through a prototype model which has undergone exhaustive tests. The new gear is especially recommended as a drive for precision machine tools.

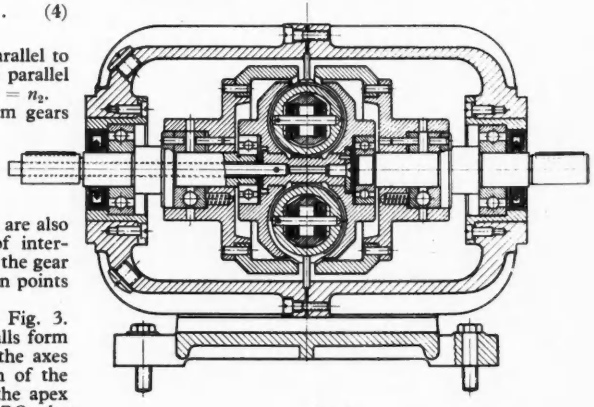


Fig. 4

# New Principles for Commutator Design and Manufacture

By F. L. LAUB. (From *Bulletin de l'Association Suisse des Electriciens*, Vol. 40, No. 25, 1949, pp. 988-1001, 8 illustrations.)

*With the new design and manufacturing principles set forth in this article, it should be possible to build commutators which will retain their shape and compactness even under unfavourable working conditions, provided they have no defects from the electrical standpoint. The practical conclusions given in the following sections will be based on an analysis of the elastic deformations of the main commutator components and the pressures by which they are generated, and formulae will be derived for determining the mechanical and thermal forces involved. The article will be continued next month.*

WHEN operating under difficult conditions, particularly with considerable overloads, some commutators have a frequent tendency to develop mechanical trouble, with flat bars, loose or distorted segments, etc., whereas other commutators of similar design are free from such difficulties.

In designing a $K$-segment commutator it is the usual practice to take the taper angle $\gamma_0$ of the bar section as being equal to $1/Kth$ of the 360 degrees of the full circumference. The bar section is usually defined by specifying its height and thickness at the top and bottom ends. The bars received from the copper suppliers are, however, only approximately of the dimensions required, and if the inevitable inaccuracies of the bar section due to the wear of the tools are also taken into account, it will be seen that the probability of obtaining the correct taper angle $\gamma_0$ is not very great. If the taper angle is greater than $360°/K$, the bars will make contact with the adjacent micanite strips only at their outer edges, and if it is smaller the contact will be at the inner edges only (see Figs. 1a and 1b).

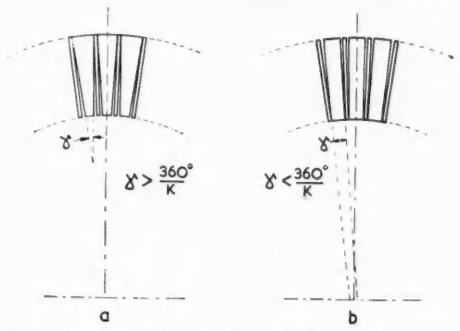



Fig. 1. **Contact conditions for laminations with a taper angle $\gamma$ larger or smaller than the nominal angle.**

As both copper and micanite are fairly elastic, when the commutator is tightened up the line contact becomes a surface contact, the width of the contact area being determined by the angular difference $360°/K - \gamma$, the thickness and the elasticity moduli of the copper and micanite materials, and the tightening pressures. The contact area normally extends over the full flank length of the bar or at least over the major portion of the latter. However, owing to the taper angle inaccuracy, there is a non-uniform deformation of the mica and the copper bars, as shown in Fig. 2.

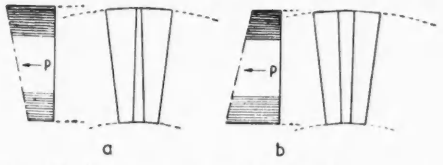



Fig. 2. **Elastic deformation of mica separators and copper laminations, with flank pressure distribution diagrams.**

Regarding the flanks of the bar sections as plane surfaces, it will be seen from Fig. 2 that in the case (a) the deformation increases linearly in the outward direction, and in case (b) it decreases in the same direction. The compressive stresses, assuming Hooke's law is applicable, then give the pressure distributions also shown in Fig. 2. If the contact does not extend over the entire flank, the pressure diagrams will be as indicated in Fig. 3.

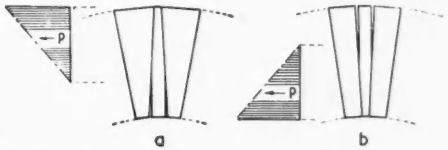



Fig. 3. **Deformation and pressure distribution when contact between laminations and separators is not effective over the entire flank length.**

If a commutator with bar sections having a taper angle in excess of the nominal value is put through truing operations for some reason or other, the area of maximum flank pressure is reduced. The commutator will then lose its compactness and has to be tightened again. In cases such as those shown in Fig. 3, these effects will be still more conspicuous. More dangerous, however, than the loss of compactness of commutators the bar sections of which have a taper angle larger than the pitch angle, is the tendency towards developing "flat bars" when subjected to considerable temperature rises during operation.

The heat generated by a commutator is developed almost entirely on its surface, as a result of losses due to contact resistance and brush friction. Consequently, the temperatures and thermal strains in the bars are greatest at the bar surface, and the lateral expansion is further increased because the bar thickness is greatest in this region. If the micanite strips are already strongly compressed, as in case (a), then the thermal pressures will probably be high enough to produce permanent deformations of the mica and copper, and the compactness of the commutator will be affected when lower temperatures are reached after stopping. As the commutator will not cool down and contract uniformly over its entire periphery, particularly when it is stationary, the bars which cool down and contract more rapidly may be forced radially inwards by the others. The outer conical caps offer no effective resistance to this displacement, since they are not compressed to any considerable extent. A flat bar section is thus obtained, although the result only becomes apparent after a fairly considerable number of overloadings and shut-downs.

When the taper angle is less than the nominal value, as in case (b), subsequent machining operations have little, if any, effect on compactness. The bars can expand transversely, under overload conditions, without creating excessive flank pressures. During the cooling process, the bars and the micanite cannot move radially with regard to each other, since they are firmly pressed together in the inner dovetail section. The danger of

flat bars being formed is thus avoided. However, the angular overlap required for this purpose must be very small to avoid the risk of obtaining commutators as shown in Fig. 3b. The bar section should therefore be designed with a taper angle smaller than $360°/K$, but the angular difference should be small enough for a closed running surface to be obtained with even moderate tightening pressures, while ensuring that the bar section will have the above advantages, which are obtained by designing for a higher flank pressure in the inner or dovetail section.

In the following sections, simple methods will be evolved to fulfil these requirements.

## FLANK PRESSURE DISTRIBUTION

For a bar section with a taper angle exactly equal to the pitch angle, that is, when $\gamma_0 = 360°/K$, the relationship (see Fig. 4) between the outer width $b_e$, the inner width $b_{i0}$, and the height $h_0$ of the bar is given by

$$b_e - b_{i0} = 2\,h_0 \tan(\gamma_0/2) = 2\,h_0 \tan(180°/K)$$

If the taper angle $\gamma$ is smaller than $\gamma_0$, then $b_i > b_{i0}$. The difference $b_i - b_{i0} = \Delta$ represents the true excess in thickness at the inner end. Then

$$\Delta = b_i - b_{i0} = (b_e - b_{i0}) - (b_e - b_i)$$
$$= 2\,h_0\,[\tan(180°/K) - \tan(\gamma/2)]$$

Assuming that micanite has a linear stress/strain relationship in accordance with Hooke's law, the elastic deformation of the strip is $\Delta s_e = s\,p_e/E_m$ (close to the running surface), and $\Delta s_i = s\,p_i/E_m$ (just above the inner surface). In these equations, $s$ = thickness of micanite separators, $E_m$ = elasticity modulus of mica, and $p_e$, $p_i$ = flank pressures between the flanks of the bar sections and the micanite separators, close to the running surface (subscript "$e$") and the inner surface (subscript "$i$"). These equations give

$$p_i - p_e = (\Delta s_i - \Delta s_e)\,E_m/s, \text{ and as } \Delta s_i - \Delta s_e = \Delta,$$
$$p_i - p_e = E_m\,\Delta/s \quad .. \quad .. \quad .. \quad .. \quad (I)$$

Although this equation does not take account of the deformation of the copper and is, therefore, only approximately true, it nevertheless gives an idea of the pressures and deformations to be considered. It shows that, for mica with a given modulus $E_m$ and a bar section with

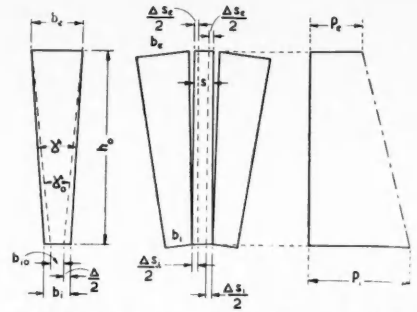



Fig. 4. **Deformation of a micanite separator and corresponding pressure distribution diagram.**

an actual excess in thickness $\Delta$, it is necessary to avoid the use of separators which are too thin, in order to maintain $p_i - p_e$ and hence the pressure $p_i$ within reasonable limits. The equation also indicates that $\Delta$ should not be too great if the mica separators are of moderate thickness, this being required to obtain a closed running surface when normal assembling pressures are applied. Furthermore, an excessive value of $\Delta$ can be compensated for by choosing a softer type of mica.

If the deformations of the copper bars are also taken into account, the results are:—

| | Elastic deformation of copper bar | of separator |
|---|---|---|
| Close to running surface | $b_e p_e/E_c$ | $s p_e/E_m$ |
| Close to inner surface | $b_i p_i/E_c$ | $s p_i/E_m$ |

$E_c$ being the modulus of elasticity of hard-drawn copper.

Let $\tau_k$ = pitch in the running surface of the commutator after assembly, and $\tau_k'$ = pitch in the inner surface. These values are determined by the equations

$$\tau_k = (1 - p_e)\,[(b_e/E_c) + (s/E_m)] \quad .. \quad .. \quad (1)$$
$$\tau_k' = (1 - p_i)\,[(b_i/E_c) + (s/E_m)] \quad .. \quad .. \quad (2)$$

(*Continued on page* 256)

CZECHOSLOVAKIA

# Strengthening the Insulation of the Terminal Turns of a Transformer Winding

By B. HELLER, J. HLÁVKA and A. VEVERKA. (From *Elektrotechnicky Obzor*, Vol. 39, No. 1-2, January, 1950, pp. 1–4, 14 illustrations.)

THE value of strengthening the insulation of terminal turns of transformers against damage by surges is a matter of controversy. While Nolen and Pesak recommend such strengthening, Elsner and Roth prefer a constant thickness of insulation.

The inter-turn and inter-coil capacitances of the end of the transformer winding change when the insulation is strengthened. Keeping the width of the coils constant then decreases the number of turns and the inductance. Regarding the winding, in first approximation, as a line, the changes in the capacitance and inductance are unfavourable, as they cause reflection of surge waves. Further, it can be shown theoretically that the improvement in voltage distribution by progressive strengthening of the insulation is so small that it does not warrant the increased production costs.

To clarify matters, calculations were carried out on a high-voltage transformer (see Fig. 1) with progressively strengthened insulation, and the results are shown in Table I.

TABLE I.

| Section of the winding | Ratio of inter-turn capacitance of strengthened and normal windings | Ratio of inter-coil capacitance of strengthened and normal windings | Ratio of the inductance of strengthened and normal windings |
|---|---|---|---|
| 1 | 0·19 | 0·68 | 0·1 |
| 2 | 0·29 | 0·82 | 0·21 |
| 3 | 0·58 | 0·95 | 0·47 |
| 4 | 1 | 1 | 1 |

The largest changes were in the values of the inductance, while those of the capacitance were compara-

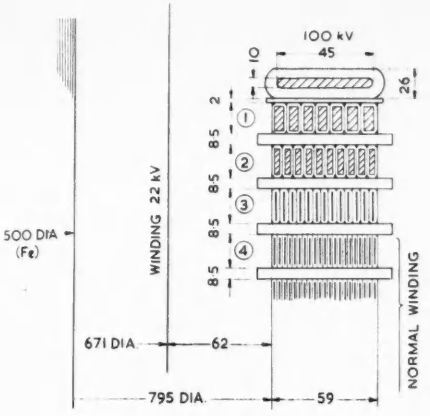



Fig. 1.

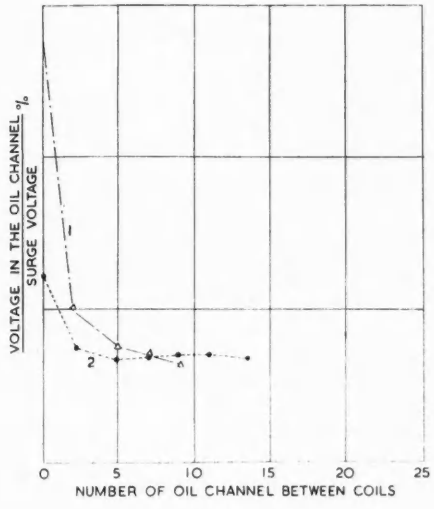



Fig. 2

tively small. The voltage distribution, therefore, did not change much, but there was a marked change in the nature of surge oscillations, these being influenced by the inductance.

To improve the voltage distribution of transformers with a rating above 35 kV, electrostatic shields are used around the terminal coils. They provide a linear voltage distribution in the first coil and improve the voltage distribution in the inner parts of the winding. Fig. 2 shows the voltage distribution of a surge as measured on a transformer without an electrostatic shield (curve 1) and with a shield (curve 2), the winding having an insulation of constant thickness.

The authors took oscillograms of a transformer winding to investigate the influence of the strengthening of the insulation on the free oscillations of the winding. These were the data of the transformer:

Diameter of the iron core, 6½ in.
Height of the core, 19¾ in.
Connecting piece of the core at the open top, during measurements.
Number of normal coils: 20 (8 turns per coil).
Number of abnormal coils 4 (4 turns per coil).

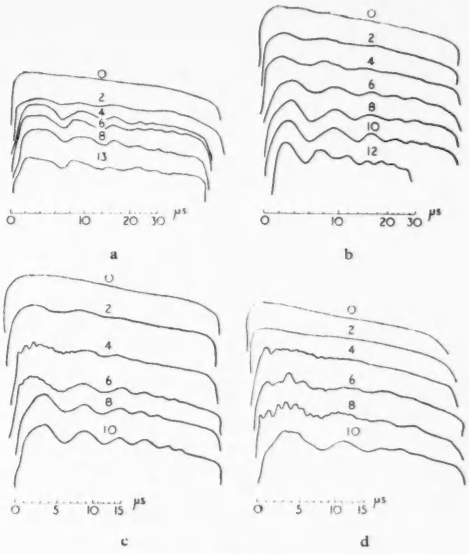



Fig. 3

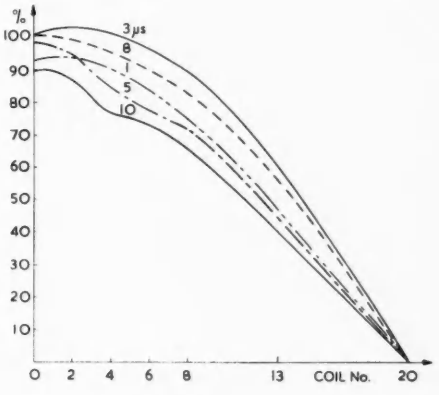



Fig. 4

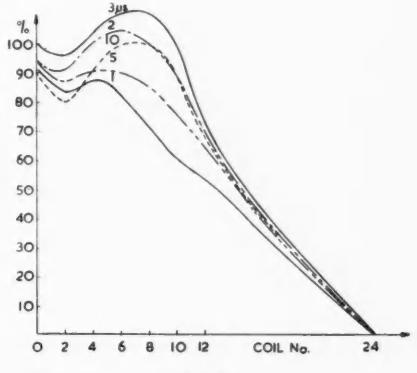



Fig. 5

Each successive pair of turns was connected parallel in the abnormal coils. The measurements were carried out with one end of the winding earthed and the surge applied to the other. Oscillograms were taken at equidistant points on the winding, the surge end being called point 0, and the other points being numbered from the surge end.

The oscillograms *a* in Fig. 3 show the surge at the points of a transformer winding consisting of 20 normal coils. The oscillograms *b* give the curves of the transformer with 4 abnormal and 20 normal coils. The oscillograms *c* give the curves of the transformer with the same number of coils as in *b*, but the distance between the abnormal coils was increased to $\frac{5}{8}$ in., from the normal $\frac{1}{4}$ in. The oscillograms *d* give the curves of the transformer with the same number of coils as in *b*, but the distance between the abnormal coils is decreased to 3/16 in, while that between the normal coils is increased to 7/16 in.

Using these oscillograms, the voltage distribution was evaluated in the transformer winding at intervals of 1, 2, 3 and 10 micro-seconds (see Figs. 4, 5, 6 and 7).

It can be seen from Fig. 5 that the large decrease in the inductance caused voltage peaks (at 3 $\mu$s) in the region of the coils 6 to 8, i.e., in the part of the winding where the insulation was not reinforced. When the terminal coils were widely spaced, as in the case of Fig. 6, this voltage distribution was somewhat better, but still worse than in the case of Fig. 4.

The voltage drops per turn in different coils are shown in Figs. 8 and 9 as a function of time for transformers with constant thickness and strengthened end insulation respectively. The inter-coil distances are equal and electrostatic shields are used. It can be seen that the voltage distribution is more favourable

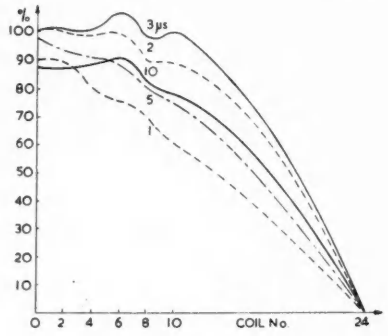



Fig. 6

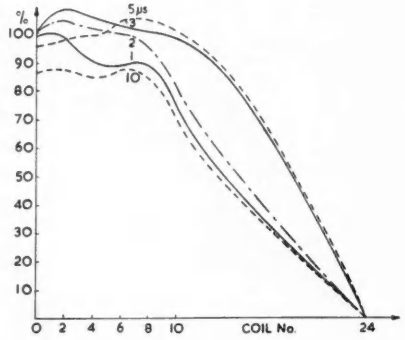



Fig 7

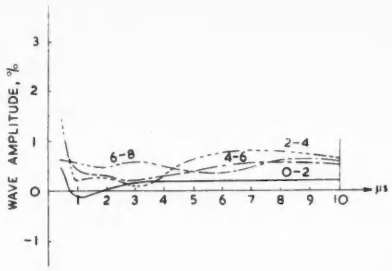



Fig. 8

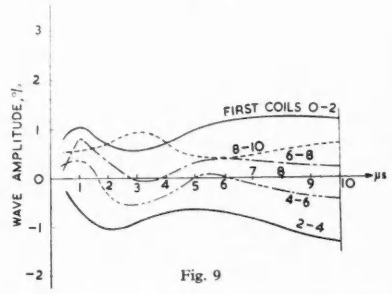



Fig. 9

in the case of the transformer with the constantly insulated winding.

It should be concluded, therefore, that transformers with constant insulation thickness are to be preferred. It is clear in this case that the maximum stress is produced by the surge in the end turns, but for a very short time only (less than 1 $\mu$s). The electrical breakdown strength of the insulation increases with a decrease in stress duration. Fig. 10 shows that when the duration is less than 1 $\mu$s, the breakdown strength increases by a factor of 4, as against the 10-second breakdown strength. Applying these facts to the case of a 100-kV transformer, with constant insulation thickness, the following calculations show the strength of the insulation in the case of a maximum surge of 550 kV.

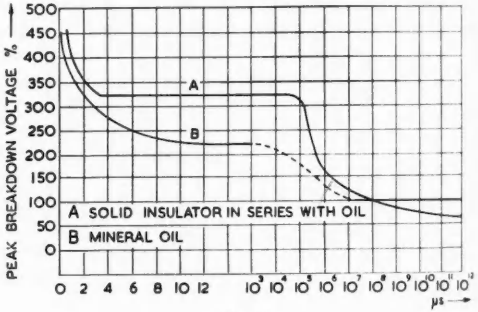



Fig. 10

Let us suppose that the voltage drop on the first coil is 70 per cent, i.e., 400 kV. With the use of an electrostatic shield, the inter-turn voltage will then be 20 kV. The insulation thickness is 0·05 in. corresponding to a 10-second breakdown strength of 38-kV peak voltage. As the surge stress is of very short duration, the breakdown strength of a turn is more than 100 kV, which corresponds to a safety factor of more than 5.

# Accuracy in Machining—Its Standardisation and Cost

By T. H. Vogel (Kearney and Trecker Corporation).

The accuracy of machined workpieces has occupied the manufacturer's mind since the very infancy of metal working. However, as long as mating parts were used in a specific assembly and were not expected to be interchangeable with similar parts in another assembly, there was little need to know the exact tolerances of, for instance, a bore or a shaft. The important thing was the amount of clearance or interference. This could easily be determined by comparison of the matching parts and was frequently left to the judgment and skill of the assembler in the shop.

As machines and factories increased in size and complexity, it became imperative to set up definite and accurate values for the sizes of parts. As a result, component parts of a machine could be finished independently in several locations and their assembly without further finishing to size would nevertheless be assured. Replacement parts for machines broken down in the field could be made to correct size directly from the original drawings.

Gradually all larger factories started introducing their own standards for dimensions and fits to facilitate this interchangeability. Then, subcontract work, as it becomes necessary especially during boom periods and times of war production, created a demand for national standards of tolerances and fits. Finally, an international unification of the various national systems was sought, chiefly by the more inter-dependent nations of Continental Europe which used the metric system of measurement. This unification should eliminate any doubts and misunderstanding in relation to the way two pieces are matched, no matter how far apart the shops are located, where they are made, or what language is spoken. It ultimately led, in 1935, to the creation of the "ISA System of Tolerances" by the International Federation of National Standardising Associations, which has since been approved as a national standard by fifteen Continental nations, including Russia, as well as by Japan and, lately, also China.

America and Great Britain, although being members of this Association, did not accept the ISA System, primarily because the metre, rather than the inch, was established as the basic unit of length. During the last war it became more apparent in the United States too, that some standardisation of tolerances and fits was urgently needed. A draft of "Recommended Tolerances and Allowances for Different Ranges of Nominal Sizes" was issued by the American Standards Association in 1947, but it only comprised tolerances and allowances for basic sizes from 0·0100 to 4·000 in., without indicating any specific fits (for further explanation see below) and the way they were to be applied in actual manufacturing. Unless this additional data is provided, such standards are of little practical help to the designer. It is less confusing to continue using the tolerances which have worked satisfactorily in the past and which are familiar from long experience.

Certainly, this lack of standard specifications for fits as well as the restricted flexibility of systems of tolerances which were formerly recommended in the United States are the main reasons why the establishment of such national standards has met with limited success. The author has visited approximately two dozen important engineering shops and cannot recall any widespread system in use. In most cases, tolerances and allowances were indicated on drawings in arbitrary figures to the tenth of a thousandth of an inch. On the other hand, most people familiar with the question agreed to the necessity of a standardisation in this field.

Some work in this direction is being done by the aircraft factories—other efforts are sponsored by the American Standards Association. As long as no final decision has been made, and probably will not be made for some time to come, it was felt that a brief description of the ISA System of Tolerances and its great flexibility would be of interest. Today, many experts see no reason why the same standards cannot be established in countries which use the "inch" as the basic unit of measurement. The only operation necessary to convert metric standards to English equivalents would involve the use of the factor '25' as a multiplier. This would be sufficiently accurate, since the values of the ISA System are already approximated results obtained with the exponential formulae on which the whole system is based.

In the second part of this article, a short investigation of the rise of manufacturing cost with increasing accuracy, based upon the ISA System, is reported. Some explanations of the system are, therefore, also necessary in this respect.

## THE ISA SYSTEM OF TOLERANCES

These standards apply particularly to fits between cylindrical parts, briefly designated as "holes" and "shafts," but can just as well be used between mating parts other than cylindrical, e.g., ways, keyways, etc.

The reference temperature is 20° C or 68° F—the same as in the U.S.A.

The general requirements which must be considered when a fit has to be selected are illustrated in Fig. 1.

### Qualities

The quality grades of the ISA System are characterised by the accuracy to which a dimension is held, i.e., by the tolerance which is allowed for manufacturing the particular dimensions. The ISA System provides for 16 "grades of quality," or just "qualities" designated IT 1 to IT 16, IT 1 being the highest quality with the smallest tolerances, IT 16 having the largest tolerances. The series IT 1 to IT 4 are almost exclusively applied to gauges and are not discussed here. Starting with the quality IT 5, the basic tolerances of each quality are rounded multiples of the unit of tolerance $i$, which itself depends only upon the dimension or nominal size $D$ of the workpiece.

$$i = 0{\cdot}45 \times \sqrt[3]{D} + 0{\cdot}001 \times D$$

in which

$i$ = tolerance unit in 1/1000 mm
$D$ = nominal size in mm

The factors multiplied by $i$ follow a geometrical progression with the ratio $\sqrt[5]{10} = 1{\cdot}58$ and determine the size of the tolerance. The tolerance series IT 6 has been arbitrarily chosen as $10i$.

It may be noted that the qualities 11 to 15 each show factors 10 times as large as qualities 6 to 10, e.g., IT 11 = 10 × IT 6.

| Quality | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Size of tolerance | $7i$ | $10i$ | $16i$ | $25i$ | $40i$ | $64i$ | $100i$ | $160i$ | $250i$ | $400i$ | $640i$ | $1000i$ |

The qualities 5 to 11 are mainly provided for machined fits, whereas the qualities 12 to 16 comprise larger tolerances as they might be applied to forging or rolling jobs.

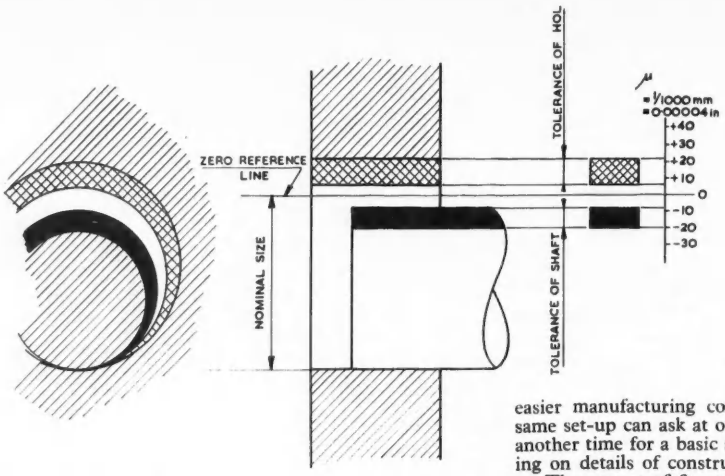



Fig. 1.
**Graphical illustration of a hole and a shaft with their respective tolerances.**

The position of the tolerance zones with respect to the zero reference line (e.g., the line 10·00000 of a 10-mm dia. hole or shaft) is indicated by letters, capital letters being used for interior dimensions (holes), and small letters for exterior dimensions (shafts). A figure between 1 and 16 added to the letter designates the particular quality.

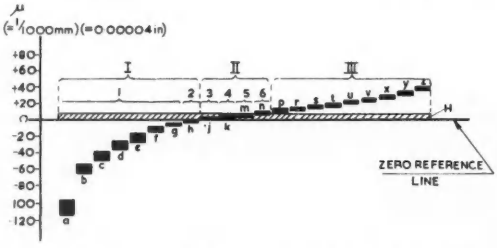



Fig. 2. **Designation of fits for the basic hole system. Hatched zone "H" = tolerance of basic hole. "a" to "z" = tolerances of corresponding shafts.**

I. Running fits
(1) Clearance fits
(2) Slide fit

II. Transition fits
(3) Push fit
(4) Wringing fit
(5) Drive fit
(6) Tight fit

III. Interference fits.

As shown in Fig. 2, 'a' to 'h' apply to the tolerance zones below the reference line with 'a' corresponding to the largest distance; the letters 'k' to 'z' apply to tolerance zones above the reference line, with 'z' corresponding also to the largest distance. This gives a series of steps from the maximum position below to the maximum position above the reference line. Independently of the quality, these letters always indicate the smallest possible distance of the tolerance zone from the reference line, and thus prescribe the minimum clearance or minimum interference between mating parts. This applies to shafts as well as to holes with few exceptions.

FITS

Although, according to the ISA system, a free association of the different shafts and holes is permitted and no strict adherence to any special system is demanded, a basic hole system and a basic shaft system were taken as the basis for its structure. Both systems are used concurrently and no special preference should be given to either one of them. It has to be decided in each application which of the two systems allows easier manufacturing conditions. Fundamentally, the same set-up can ask at one time for a basic hole and at another time for a basic shaft tolerance, merely depending on details of construction.

The system of fits provides for three groups of fits (Fig. 2):

I. CLEARANCE FITS (running fits), in which the assemblies of parts always have a certain amount of clearance and are free relative to one another.

II. TRANSITION FITS, which, according to their character, are intermediate between clearance and interference fits and may have either clearance or interference.

III. INTERFERENCE FITS, in which the components, before assembly, always overlap in size to some extent and after assembly remain more or less fixed together.

Each manufacturer is entirely free to select the fits he needs for his particular job within the wide range of possible combinations offered by the ISA System. To make his choice easier and to avoid too large a variety of fits used in the shops, a number of "recommended fits" has been selected for all ordinary requirements of mechanical engineering and precision production.

As will be mentioned once more later on, the actual clearances or interferences have to be evaluated by using the medium deviations and not by comparing extreme values of two tolerance zones.

## ACCURACY VERSUS COST OF MACHINING

Some experts have stated that when the equipment of the shop and training of the personnel have been adjusted to a desired range of precision, comparable accuracy can be achieved with relatively little effort. This statement is true within limits, but the relationship is, however, always relative. The production of a certain quality will be less costly in a shop which has been equipped for the required precision than in another shop which is better or worse equipped and also has a working force which is accustomed to more exact or less exact work. In each case, there is a certain optimum. However, taken as an absolute, high precision is definitely more expensive because primarily it requires better and more expensive machinery, and, secondly, more highly trained men are necessary for the operation of these machines. If pieces of low accuracy have to be made in a shop which is adapted to high-precision work, they will be comparatively expensive. The rates are higher on expensive machinery and the operators are not used to producing lower quality work. We see, therefore, that there is a very definite close relationship between accuracy, production, machinery available, and the skill of workers. If we ask for a precision higher than necessary, we not only make the

piece itself more expensive, but increase the production costs for pieces of lower precision as well. Therefore, good practice will never specify a higher accuracy than is absolutely necessary. There is also the danger that the shop will not observe the directions of the engineering department any more, if it finds out that frequently a lower accuracy than requested will fulfil the purpose just as well. This may lead to grave mistakes when a piece has to be very accurate. In terms of tolerances, it is important, therefore, that the quality of a fit be chosen in such a way that the next greater tolerance would make the workpiece unsatisfactory.

The cost increase with higher accuracy has, so far, merely been stated, unsupported by any proof. Unfortunately, a search for literature containing data concerning the problem of accuracy of manufacture in relation to its cost was almost without results. In most cases, general statements, unconfirmed and unsupported by any measurements, have been made.

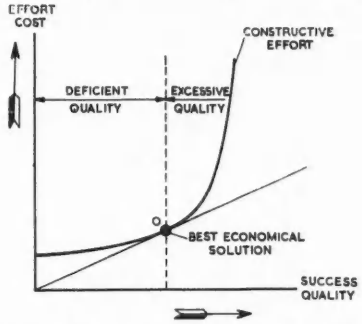



Fig. 3. **Illustration of the optimum point in manufacturing. Point O represents the best quality obtainable with relatively low cost.**

The following statement has been taken from a thorough and complete discussion of this subject in a book by P. Leinweber*: "The thoughtlessly written 0·001 or 0·0001 waste more money and manpower than some design that is poorly planned." In a paper published in 1932 by the VDI†, a curve (Fig. 3) was was found which is quite informative but unfortunately does not give any information regarding the means and methods of its origin.

Since records of such investigations were not available from outside sources, the only alternative was to take some basic measurements in the shop. It appeared obvious that at the beginning, these tests had to be confined to a simple case in order to obtain useful results. All further external influences such as overhead of machine, quality of worker, number of pieces, material and hardness of surface were not taken into consideration.

The ISA tolerance system was chosen as a means of measuring the quality of the test pieces. This had a great advantage in that it permitted staying within normal shop production limits and did not require unusual effort on the part of the operator. Further, the necessary control instruments such as regular snap gauges were already available.

To approach as closely as possible actual production conditions, a test piece was designed which had two diameters and a collar, all three of a specific accuracy (Fig. 4). One piece each of the ISA qualities IT 5, 6, 7, 8 and 10 was produced. The turning remained the same for all pieces, which meant that 0·3 to 0·4 mm

*"Passung und Gestaltung," Dr. Ing. P. Leinweber, Springer, Berlin, 1942.

†"Wechselbeziehung zwischen Konstruktion und Herstellungskosten," VDI, Berlin, 1932.

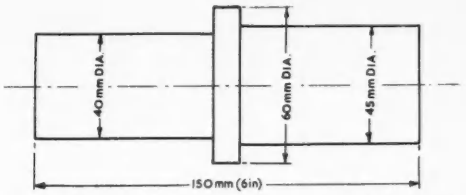



Fig. 4. **Test piece for experiments illustrated in Figs. 5, 6 and 7.**

(0·012 to 0·016 in.) stock was left. The following grinding operation should serve to demonstrate the different time requirements dependent on quality. It was thought that the influence of routine which a worker acquires when he makes a larger number of similar pieces would affect the necessary grinding time. The pieces would, therefore, not be made according to quality, but according to a specified sequence.

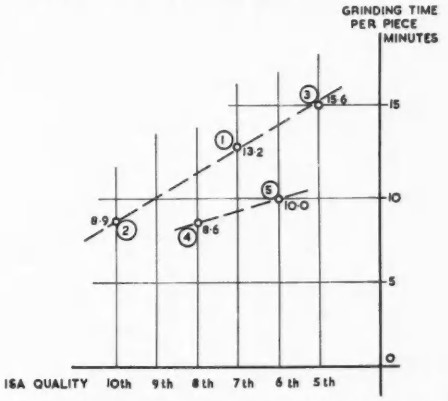



Fig. 5. **Results of grinding test pieces (Fig. 4) to various accuracies (ISA qualities).**
(1) to (5) sequence of production of test pieces. This shows that routine of operator was of greater influence on grinding time than required accuracy. Therefore, test not conclusive.

The results of this first series of tests can be seen from the chart in Fig. 5. It is clear that all happenings which are under human influence, such as the grinding of these test pieces, are subject to heavy fluctuations. An especially reliable and regular operator was chosen to do the work. To average the variations, all grinding times for the three diameters of one particular quality were added, but no definite curve through the five points measured could be drawn. The effect of the sequence of production along with the routine of the worker turned out to be more pronounced than the difficulties of the job itself.

Two routine curves were then plotted empirically (Fig. 6), one straight and one approximately exponential.

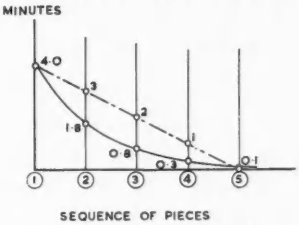



Fig. 6. **Two empirically plotted routine curves.**
These indicate how the grinding time decreases, when more pieces are made, and the operator acquires greater efficiency.

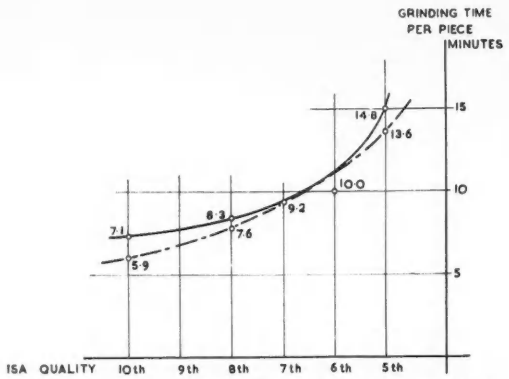



Fig. 7. **Curves obtained when values of Fig. 5 are diminished by values of Fig. 6.**

It might be thought that the working time would decrease in some such manner depending on the number of parts produced. If the measured grinding times (Fig. 5) were decreased by those of the theoretical routine curves (Fig. 6), the two curves in Fig. 7 would be obtained. The latter ones correspond to what could be expected as a result of this test. Thus, it is shown only that the result of this test as such is not usable.

In a second series of tests it was decided to have ten pieces of each quality made so that the influence of routine would be very much diminished. All other conditions were kept the same as much as possible. The identical material was used and the same operator employed. The test piece was simplified by eliminating the collar. A sequence of operation was established in which test pieces of the qualities 6, 10, 8, 5, 12 and 7 were to be made consecutively.

The results of this second series of tests can be seen in three diagrams. In Fig. 8 the grinding time is plotted versus the size of the tolerance. The steep increase of the curve with increasing accuracy is much more obvious here than when the time is plotted in relation to the ISA Standard (Fig. 9). The time measured comprises the actual grinding and handling time. The grinding time includes the time used for measuring the workpiece with a snap gauge. The handling time includes chiefly machine adjustments and dressing of the grinding wheel. This non-machining time increased noticeably with increasing accuracy. For the production of the ten most accurate pieces (fifth quality) it was necessary to dress the wheel three times, while for the seventh quality, only one dressing was sufficient for the whole series of ten pieces. Particularly informative is Fig. 10, which indicates the average number of measurements required in order to finish a diameter. It rises linearly and more steeply than the time curve. Thus, the working time increased less in proportion than other requirements, such as nervous strain and intensified concentration, which are made upon the operator when higher precision is required. Here we are confronted with a condition which is not often given sufficient consideration when the difficulty of an operation is appraised and piece rates are set.

These curves give only an approximate idea of the increase of manufacturing cost with higher accuracy. As all investigations of production economy are subject to human and other influences, which are never constant, only a great number of tests could lead to a reliable answer. The above results should not be taken as absolute, but it is believed that the more or less exponential rise of the curves approximates actual conditions fairly well.

Now, since it was proven that the effort increased with higher accuracy, the two following questions arose:

(1) Are there any pieces made in this shop which are more accurate and, therefore, more expensive than necessary?

(2) Are the pieces really as exact as is required by the drawing?

Since the drawbacks mentioned previously are more pronounced with greater accuracy, main atten-

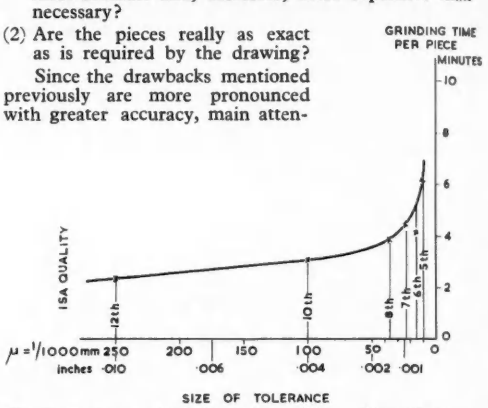



Fig. 8. **Increase of grinding time with smaller tolerance. Of each ISA quality, ten test pieces were made.**

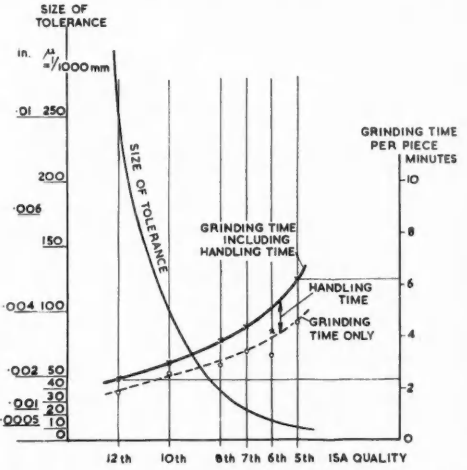



Fig. 9. **Values of Fig. 8 plotted over ISA qualities. "Size of tolerance" curve shows exponential decrease of ISA tolerances with higher ISA qualities.**

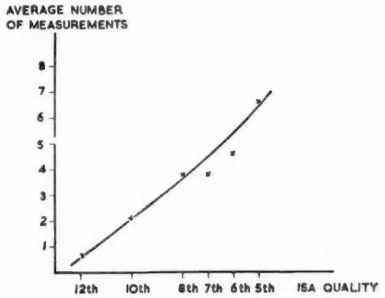



Fig. 10. **Number of measurements with snap gauges that were necessary to finish one diameter of test-piece.** Note steeper rise of curve than that of corresponding grinding times (Fig. 9).

tion was focused from the beginning upon the finest ISA quality, IT 5, used in the shop. For this purpose, a number of workpieces with " h 5 " tolerances were taken out of the normal production and checked in a test room. In most cases, an electronic comparator, which is easy to handle and has an accuracy of ± 0·001 mm (0·00004 in.), was used. The results can be stated as follows:—

Out of 220 pieces which had "h5" tolerances, 55 per cent were scrap, which means 55 per cent of the dimensions were not within the required tolerances.

This result was not very favourable, especially since it was found out later that most of the scrap pieces could be used the way they were, and were suitable for their purpose. Unfortunately, it was not possible to establish how many of these pieces could not actually be used, since very often the actual scrap was determined chiefly during assembly operations. However, this picture must not be interpreted incorrectly, since these statistics cover a period of only two months and were also affected by certain manufacturing shortcomings due to the introduction of new finishing operations which have been improved in the meantime.

In spite of this, it was concluded that a tolerance of the 5th quality is very hard to obtain with the means of production and measurement available in the test shop. Therefore, this quality is to be avoided wherever it is not absolutely necessary, and this is possible with few exceptions.

Especially in cases where a very tight fit, with no interchangeability of the parts involved, is needed, it will often be cheaper to produce the pieces a little less accurately and later select parts so that the required fit is obtained. In mass production, this is often done by dividing the lots of pieces into groups of various sizes with an automatic measuring and segregating device.

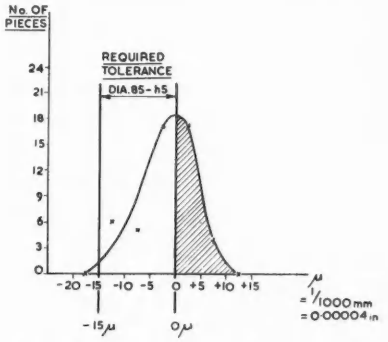



Fig. 11. **Result of 50 finished diesel engine wrist pins checked in laboratory with electronic comparator.**
Thirty per cent of pieces showed oversize.

These distribution tests of a great number of pieces led to interesting observations about the frequency of occurrence of individual sizes and the relationship to the nominal tolerance. Two particularly informative curves are reproduced in Figs. 11 and 12. The first one shows the sizes of 50 Diesel engine wrist pins of 85 mm dia., compared with the limits of the required tolerance zone of 85 — h 5. Thirty per cent of the pins were oversize, but since a clearance of 0·080 to 0·120 mm for the wrist pin in the piston was foreseen by the drawings, this oversize did not affect the use of the pieces. Here we have a typical example, where a very high precision had been asked for without any justification.

The graph in Fig. 12 shows the influence of an additional disturbing factor. Not only were 30 per

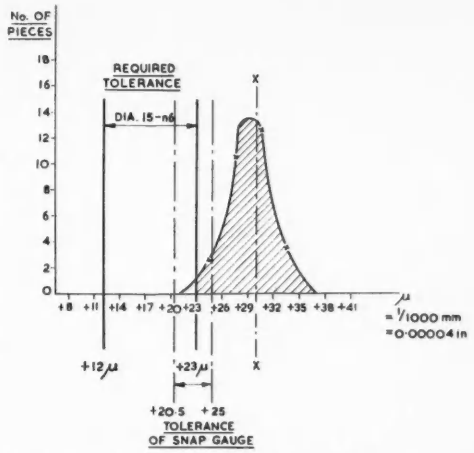



Fig. 12. **Result of checking dowel screws with electronic comparator.**
All pieces were oversize, but snap gauge used by operator and inspector had been worn beyond limit. Line x ——— x indicates actual size of snap gauge when controlled to find out origin of errors in size.

cent of screws larger in diameter than the actual size of the snap gauge used for checking, but the gauge had worn so much that it was 0·005 mm oversize, when checked to discover the cause of the existing discrepancies in workpiece size.

A comparison of many such distribution diagrams indicated the same trend, namely, that they have the characteristic bell shape of a probability curve and lie near the upper limit of the tolerance zone instead of being centred between both limits.

This observation illustrates that in the shop there is often an incorrect conception of the significance of a tolerance. Shop men many times incorrectly believe that an attempt should be made to approach the upper limit or the " Go " side of a tolerance zone. Instead, the effort should be aimed at staying midway between the limits. There then remains enough play on both sides to avoid having scattered pieces beyond the limits. Even so, there are still sufficient factors which cause all shaft measurements to tend towards the upper limit:

(1) The fear of the operator to remove too much material and make scrap by falling below the low limit.
(2) The wear of the gauge.
(3) Too much pressure applied during measurements. When the worker is in a hurry, snap gauges are often forced over the pieces.
(4) Temperature of the gauge in the hand: If a large number of pieces has to be made, it may happen that the operator keeps the gauge in his hand during an entire day. The gauge then acquires the body temperature while the workpiece might be from 25 to 50° F cooler. The result is a possible deviation in tenths of thousandths of an inch.

The curves showing distribution of frequency of occurrence finally lead to another important observation about fits and their selection. Whenever larger series of shafts as well as holes have been measured accurately piece by piece, the distribution of the frequency of all measurements results in a bell shaped curve. As just mentioned, considerable effort should be given to locate the maximum of this curve as close to the middle of the tolerance zone as possible. Relatively few pieces will then lie near the limits of the zone. In assembling a shaft and a hole manufactured according to this principle, the prevailing clearance or in-

terference becomes the difference between the mediums of the two tolerance zones of the hole and the shaft. As the majority of all pieces is concentrated around these averages, the probability that two pieces of extreme sizes will be put together is very small.

In selecting a fit giving a desired clearance or interference, a designer should, therefore, consider the centre of tolerance zones and not the extreme values, as is often done in practice.

## CONCLUSIONS

The progressive increase of working effort and the simultaneous increase in cost of production with requirement of greater accuracy has been proved. The slope of the curves shown here can only be considered as an indication, since, with all measurements under the influence of human and other variables, only the average of a very large number of tests could lead to reliable results.

In connection with the above investigation, particular problems have arisen and require further clarification:

It has been proved that close tolerances are very difficult to maintain with the production and measuring equipment available in the average shop.

A considerable percentage of the pieces measured was beyond the prescribed limits of tolerance. However, the majority of those pieces could be used without any extra work and, as far as is known, have given no cause for difficulties in service. With few exceptions, an accuracy as stated on the drawings was not necessary for those particular pieces. The next greater tolerance or lower quality of fit was completely satisfactory.

In manufacturing dimensions with tolerances, the average or median between the two limits of the tolerance should be aimed at, to prevent having scattered pieces, which always occur, fall beyond limits and become scrap. Likewise, the median of a tolerance zone should be taken into consideration when determining the amount of clearance or interference given by a particular fit.

FRANCE

# Steel Protection by Chromium Diffusion

By P. GALMICHE. (From *Revue de Métallurgie, France*, Vol. 47, No. 3, March, 1950, pp. 192-200, 11 illustrations.)

CORROSION starts from the metal surface and the metal can, therefore, be protected if only a thin surface layer is alloyed with chromium by the diffusion process. This process leaves the mechanical qualities of the work-piece unaltered and saves a large quantity of the expensive alloy, as compared with the fully alloyed piece. The alloyed layer is then an integral part of the work-piece, with high values of ductility, mechanical strength, resistance to corrosion, and hardness in some cases. The diffusion process is most profitable where steel parts have to be protected against atmospheric corrosion, against hot corrosion accompanied by thermal shock (gas turbines), and against wear at high temperatures.

Chromium diffusion may take place by contact between work-piece and fine chromium powder, in chromium chloride salt baths, or in a hydrogen atmosphere charged with chromium chloride vapours. The vapour process can be conducted at a lower temperature (1000° C) than the others, and usually results in a greater depth of penetration. A brilliant surface, that of electrolytic chromium, is obtained on 0·1 C-steel, whilst the surface of medium C-steels and cast iron is rather dull after diffusion. The depth of penetration depends on the chromium content at the surface reached after a certain diffusion time, the temperature and the time of diffusion. If the core of the work-piece is dissolved in nitric acid, a surface zone with a minimum content of 13 per cent Cr is left intact. Assuming that this constitutes the protective case, it is found that its thickness in 0·1 C-steel is 0·004 in. after three hours of diffusion at 1000° C, and 0·01 in. after 6 hours at 1100° C. The chromium content at the original surface is then about 50 per cent. The depth of penetration in 0·4 C-steel and cast iron is much smaller; moreover, cast iron cannot be treated above 950° C. The structure of the 0·1 C-steel after chromium diffusion shows a surface layer of the solid solution and a grain structure continuing through the chromised layer into the core. With 0·4 C-steels, however, a continuous zone of chromium carbides covers the surface and is due to the migration of the carbon towards the infiltrating chromium. This carbon reaction also prevents attainment of a greater depth of diffusion in medium and high-carbon steels. The 0·1 C-steel retains the same hardness of core and chromised case, whilst the chromium carbide layer of the higher C-steels is much harder than the core. The mechanical properties of the core may be restored by a subsequent heat treatment if required. The chromised case of low C-steels is perfectly adherent and ductile, and thus resistant against shock, vibration, and brittle failure. In higher C-steels, however, the case, although perfectly adherent, is brittle throughout.

The chromised surfaces resist nitric acid attack at all concentrations and temperatures. By dissolving the core in nitric acid, very thin-walled hollow pieces of complicated shapes may be obtained. Alkaline corrosion is resisted practically indefinitely by the case of high C-steels, but the mild steel case may show some pitting after a considerable time. At temperatures up to about 850° C, the chromised layer offers perfect protection against dry high-temperature corrosion, the loss in weight being very small even after a long time. At higher temperatures, however, the chromium tends to diffuse towards the core, and corrosion starts when the chromium content at the surface falls below a critical figure. Thermal shocks by sudden air quench from 800° C do not produce any cracks in the chromised layer, and test specimens were found to withstand more than 100 such shocks.

If greater depths of penetration are required with high-carbon steels, the surface may be decarburised prior to diffusion. If, after diffusion, the steel is nitrided, the surface becomes extremely hard and wear-resistant, and corrosion resistance is further improved. Other metals, e.g., nickel and cobalt, may also be chromised, but highly refractory metals such as tungsten or molybdenum resist the diffusion. Aluminium, silicon, zirconium, or mixtures of these with chromium, may be introduced by diffusion. An admixture of aluminium to chromium increases the depth of diffusion, but slightly reduces resistance against high-temperature corrosion. However, with a high Al content, a case of 0·02 in. depth was obtained after 4 hours at 1000° C, with 15 per cent Al and 2·5 per cent Cr on the average, and this provided a good protection against corrosion even at 1050 to 1100° C. The alloyed case can again be nitrided for wear resistance. Silicon also increases the depth of penetration, whilst zirconium increases the resistance against high-temperature corrosion. By a suitable choice of the components, different qualities of the case can be obtained.

# PRODUCT DESIGN AND DEVELOPMENT

## The Design of Manual Controls

Applying the benefits of their war-time experience to peaceful uses, engineers have become increasingly aware of the human aspect of the man-machine team. Anatomical, physiological and psychological factors are equally applicable to the housewife operating her electric iron, the machinist his lathe and the pilot his controls. This is simply an acknowledgment of the fact that appliances are handled and machines are operated by human beings.

Our subject thus covers grips and handles as fitted to all sorts of appliances and portable tools, grips and handles attached to levers, and, more particularly, machine controls.

The designer certainly does not need to become an expert in anatomy to be able to evaluate " human factors," but a knowledge of hand and body dimensions, posture and its relation to fatigue is necessary. In general, he will have to concern himself with the shape and size of the grip or control, as the case may be, and with its relation to the location and size of other controls and the movements of the operator.

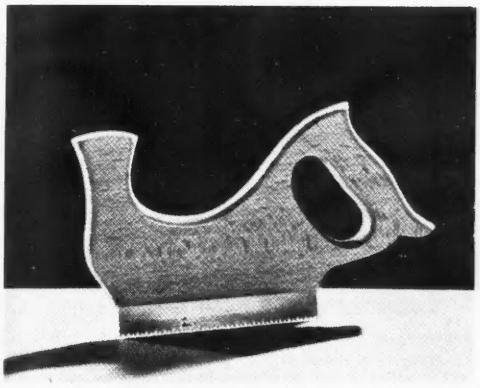


Fig. 1. **Dovetail saw. Handle made of Danish beechwood.**

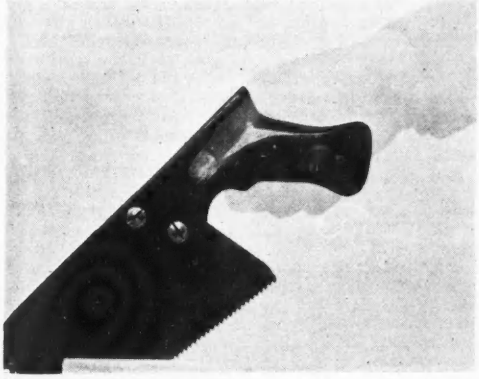


Fig. 2. **Handsaw with new form of handle. The gripping advantages are evident.**

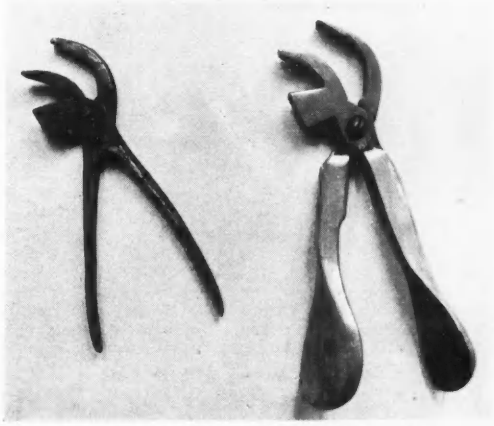


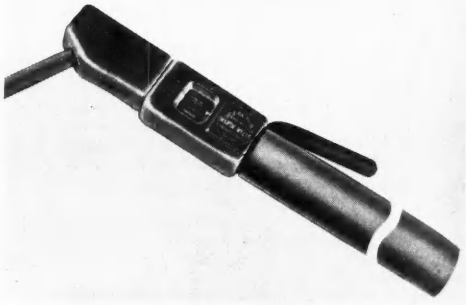
Fig. 3 (left). **Old form of pincers for shoemakers.**
(right) **New form of pincers for shoemakers.**

Fig. 4. (Top) **New type of scissors for shoemakers.**
(Centre) **Scissors with spring.**
(Bottom) **Scissors of usual form.**

Let us illustrate a few handles in order to show how the functional requirements differ from case to case. In Fig. 1 a dovetail saw is shown[1], the shape of which is determined by that peculiar process known as " dovetail cutting." This consists of a forward push with the right hand, a pull with the left thumb, and a backward pull with the fingers of both hands. It is claimed for this tool that its handle " fits the hand like a glove." The shape of this handle is a traditional one, having been in use for many decades. There is a danger of no thought being given to the improvement of these old tools of the craftsman because they have been known for so many years. This has been fully realised by Professor Kovár, who was not content to continue along

Fig. 5 (left). **Detail of the model of a new milling machine by Prof. Kovár. Control wheel designed for identification by sense of touch.**

Fig. 7 (below). **Electrode holder type 6S by Martin Wells, Inc., Los Angeles, California, showing tubular handle, cam lever and adjusting nut in the body insulator.**



traditional lines. He looked at these handles with a fresh mind and found that there was room for improvement[2]. His handsaw, Fig. 2, is provided with a new type of handle which is an example where due consideration to anatomical principles has been given in design. The size and shape of the areas through which the tool loads are transmitted to the hand must be such as to safeguard against the possibility of corns and blisters appearing on the operator's hand. In many instances, this leads to a complete departure from the traditional types of handles. Some examples of tools designed by Prof. Kovár are shown in Figs. 3 and 4,

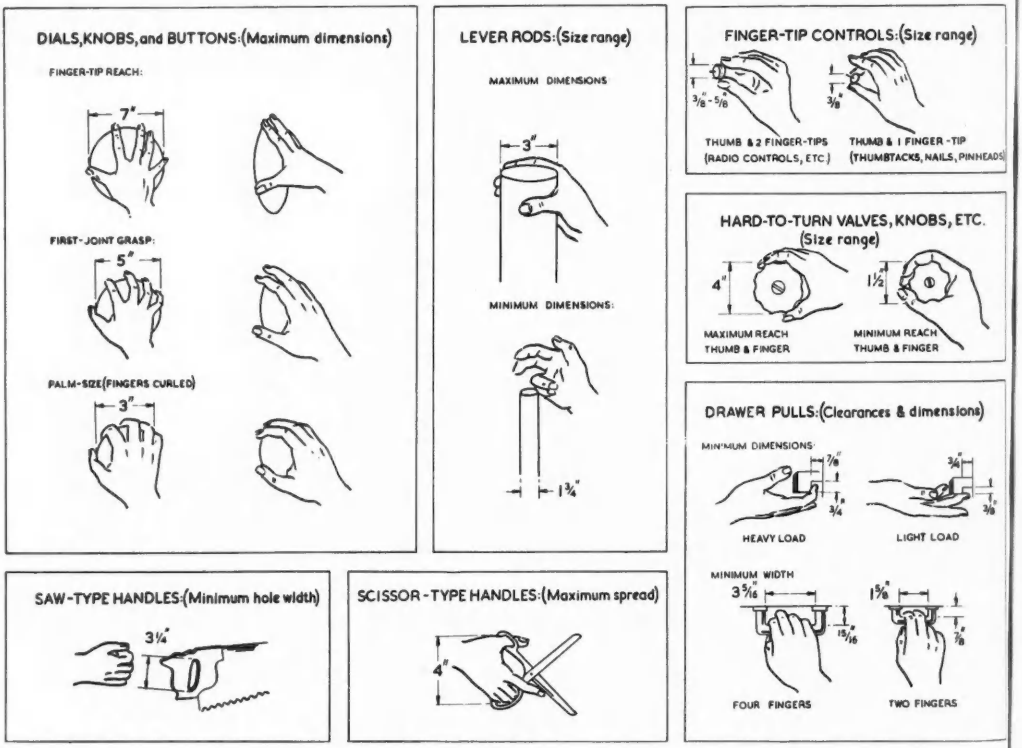



Fig. 6. **Minimum and maximum handle sizes according to the U.S. industrial design organisation of Van Doren, Nowland and Schladermundt.**

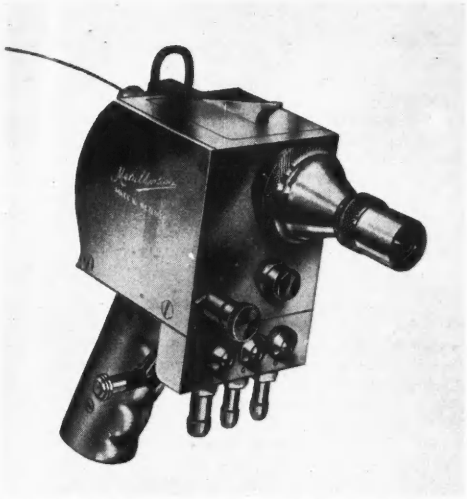


Fig. 8. **Metal spraying gun, Mark 16, with pistol handle and slide button developed by Metallisation Ltd.**

Fig. 9. **Chobert pneumatic riveter type D (2000 rivets per hour, $^1/_8$ in. to $^3/_{16}$ in. dia., steel or light alloy).**

and the shapes developed give a good illustration of the application of anatomical principles to design.

Handles and controls of machines are closely akin to the grips and handles of hand tools, so that, therefore, in this case also anatomical considerations should guide the designer, it being necessary that such parts be readily distinguishable by the sense of touch. Fig. 5 shows this principle as applied to the control wheel of a machine tool. It can be seen that correct design along these lines deviates from traditional shapes. We shall refer later in this article to other aspects of manual control design with particular reference to machine tools ; at this stage, it may be of interest to show how the dimensions of the human hand influence handle design and determine handle sizes. The first duty of the designer is to ensure that handles, knobs, etc., are large enough, but not too large, to be easily grasped, and that proper clearances are provided for fingers, etc.[3] Some guidance as to the allowable size ranges may be obtained from Fig. 6, although these may need critical revision for each particular problem according to functional requirements.

In most products there is a " handle " problem. Be it an electrode holder, Fig. 7, a metal spraying gun, Fig. 8, a pneumatic riveter, Fig. 9, or a jointing or panel plane, Fig. 10, the mode and duration of the operation and the weight of the tool are paramount factors in

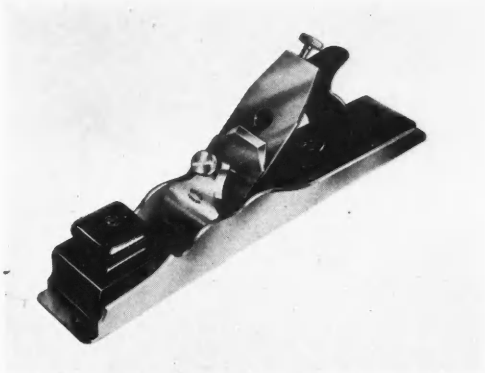


Fig. 10. **Steel jointing and panel plane by Norris Planes & Tools Ltd.**

deciding the type of handle and finger grips. Generally, for sustained use and light load, a smooth handle is employed, while for tight gripping of short duration, serrations provide the answer. In the case of the electrode holder, Fig. 7, the holder is used for long periods for a heavy hot job. The main consideration is to keep the holder cool, the handle being simply a smooth tube. Serrated handles are used for the pistol-type grips, as shown in Figs. 8 and 9. Thumb location is another point that needs careful watching. The more conventional saw-type handles, Figs. 1 and 10, score on this point, although Fig. 2 indicates perhaps a better solution.

Switches and handles are to be considered conjointly in their design and not as separate items. We have the choice of a trigger, lever (note cam lever on top of handle, Fig. 7), push button (Fig. 9), and slide button (Fig. 8). There are no hard and fast rules here, but it is obvious that the handle must be so designed as to allow easy operation of the switches. The angle and position of the handle should be such that the tool should be in perfect balance during switching.

The first considerations in the selection of the material for handles are production and price factors as well as suitability for the purpose. Spool-type handles are often copy-turned in steel or light alloy. Serrated pistol-type handles are generally cast or die-cast. Of course, the traditional material, especially for saw-type

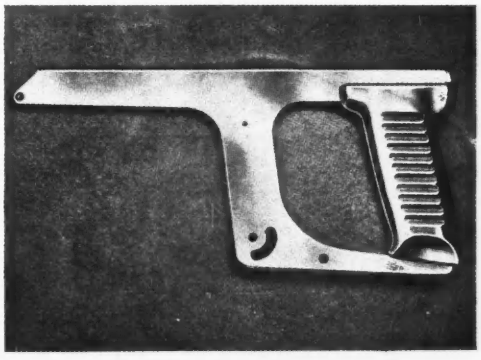


Fig. 11. **Moulded-on plastic handles, injection-moulded directly on steel hacksaw-frames.**

These cellulose acetate " pistol-grip " handles withstand separation and twisting stresses and add strength and rigidity to the metal frames. Produced by the F. J. Kirk Molding Co., the handle units clean easily, will not rot or crack, and reduce the number of assembly operations that were formerly required.

Fig. 12. **" Modernair CV Series " Control Valves. Identical housing assembly for all models, permitting hand, foot, cam, electrical or pressure pilot operation. Manufactured by Modernair Corporation, California.**

handles, is wood, and this material still holds the field. Nevertheless, for a number of reasons plastics have advantages as materials for handles. Among these advantages are thermal and electrical insulation and, in many cases, ease of assembly[4]. Fig. 11 shows an example of a modern application of plastics to handle design, in which the handle is moulded integral with a steel hacksaw frame.

The wide variety of choice available to the designer of controls can be illustrated by Fig. 12, which depicts a number of control valves, all for the same pipe size, but actuated differently, although the body assembly for all models is identical. Hand, foot, cam, electrical or pressure pilot operation is possible and, in most instances, one can be converted to the other without dismantling the valve. The foot-operated valve permits close-to-the-floor operation, which has many useful applications.

Levers constitute part of the controls of almost every type of machine. Welding readily lends itself to the building-up of simple and efficient controls, examples of which are shown in Fig. 13. This figure and the following three are taken from a " Machine Design Sheet " of the Lincoln Electric Co., Cleveland, Ohio.

When properly designed and built, lever components can improve the operating efficiency of any mechanism by transmitting greater working loads with less dead weight in working parts. On high-speed machinery especially, welded steel levers are desirable to maintain efficient performance by reducing the weight-inertia factor, thus eliminating excessively high working stresses and resultant wear on working parts.

The problem of correctly designing levers is greatly simplified when the requirements of the lever are broken down into their three basic elements : the hub, strut and linkage connection. These are pictorially represented in Fig. 14. The basic laws of machine design govern the dimensions and generally result in weight saving together with cost reduction compared with cast iron. The cost, of course, is dependent on the number of items to be made and the number of components involved.

A threaded adaptor welded to the end of the strut can be used for mounting plastic knobs. An alternative design of hand lever is made by welding a pre-machined handle to the strut, Fig. 15. If an offset is required, an adaptor can be formed accordingly. Foot treadles are easily made up by welding a plain rectangular plate to the strut, Fig. 16. Floor plate is often used to provide a good foothold. The linkage connections on either or both of the ends of the lever are governed by the fundamental requirements of the lever, namely, power, hand or foot operation. As shown in the diagrams, linkage connections are simply cut from plate or standard shapes and welded to the strut or hub member, as required. Of great importance to the designer is the flexibility of weld-fabricated construction, allowing the designer to alter any dimensions to improve machinery performance without involving costly pattern changes.

We have already implied that war-time experience has shown the results of insufficient consideration being given to " human factors " in critical controls for the Armed Forces, controls which were otherwise mechanically perfect.

Both in England[5] and in the United States[6], research work has been conducted which has shed considerable light on the problems involved. A more recent American paper[7] reported a study, the purpose of which was to determine the factors making for optimum control and speed of usage of handwheels, cranks and crossbars, consistent with closely controlled tolerance limits. For each type of control, i.e., wheel, crank and cross-bars, the following variables were introduced. (1), size of control, (2) location of the control relative to the operator, both as to height and angle of inclination, (3) work load, i.e., frictional torque applied to the shaft of the control. The results of these performances are tabulated in Table I and are self-explanatory. It will be evident from a study of these results that, e.g., cranks are better than handwheels at a height of 36 in. above floor level.

The conclusion to be drawn from these investigations is that seemingly simple factors, which have long

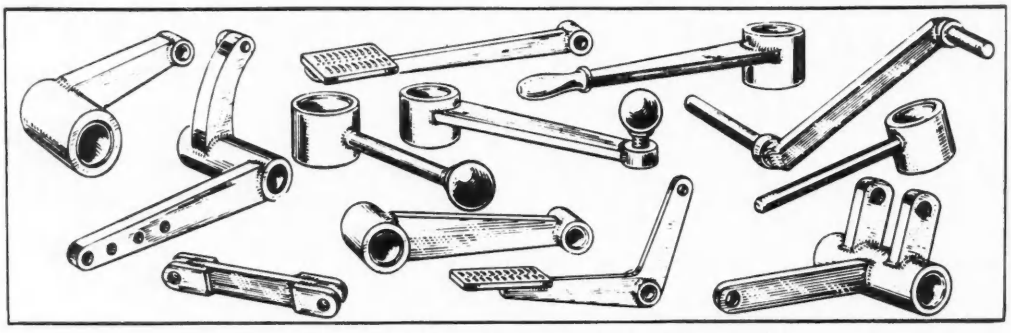


Fig. 13. **A variety of welded controls, for power, hand and foot operation.**

TABLE I.—PERFORMANCE TIMES FOR THREE TYPES OF MANUAL MACHINE CONTROLS.

| Operating Position | Height above floor (inches) | Type of control | Torque (in.-lb.) | Size of Control: 3 in. dia. Wheel or 1¼ in. rad. Crank | | 6 in. dia. Wheel or 2½ in. rad. Crank | | 8 in. dia. Wheel or 3½ in. rad. Crank | | 10 in. dia. Wheel or 4½ in. rad. Crank | | 16 in. dia. Wheel or 7½ in. rad. Crank | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Time[1] | %[2] | Time | % | Time | % | Time | % | Time | % |
| 0 | 24 | Wheel | 0 | 20 | 105 | 19 | 100 | 21 | 110 | 25 | 132 | .. | .. |
| | | | 20 | 26 | 137 | 19[3] | 100 | 22[3] | 116 | 24[3] | 126 | .. | .. |
| | | | 40 | 45 | 196 | 24 | 104 | 24 | 104 | 23 | 100 | .. | .. |
| | | | 90 | .. | .. | 39 | 139 | 34 | 122 | 28 | 100 | .. | .. |
| 0 | 36 | Wheel | 0 | 21 | 100 | 21 | 100 | 22 | 105 | 24 | 114 | 22 | 105 |
| | | | 20 | 32 | 152 | 25 | 119 | 23 | 110 | 21 | 100 | 22[3] | 105 |
| | | | 40 | 52 | 236 | 29 | 132 | 24 | 109 | 22 | 100 | 22 | 100 |
| | | | 60 | .. | .. | 34 | 148 | 25 | 109 | 23 | 100 | 23[3] | 100 |
| | | | 90 | .. | .. | 42 | 175 | 32 | 133 | 30 | 125 | 24 | 100 |
| L | 36 | Wheel | 0 | 22 | 105 | 21 | 100 | 23 | 110 | 22 | 105 | .. | .. |
| | | | 20 | 29 | 145 | 24 | 120 | 22 | 110 | 20 | 100 | .. | .. |
| | | | 40 | 51 | 232 | 30 | 136 | 25 | 114 | 22 | 100 | .. | .. |
| | | | 90 | .. | .. | 52 | 168 | 38 | 122 | 31 | 100 | .. | .. |
| 0 | 36 | Crank | 0 | 18 | 103 | 17 | 100 | 18 | 103 | 18 | 103 | 20 | 118 |
| | | | 20 | 27 | 142 | 19 | 100 | 19 | 100 | 19[3] | 100 | 20[3] | 105 |
| | | | 40 | 46 | 230 | 22 | 105 | 22 | 105 | 20 | 100 | 20 | 100 |
| | | | 90 | .. | .. | 31 | 141 | 27 | 123 | 22 | 100 | 23 | 104 |
| 90 | 39 | Wheel | 0 | 19 | 100 | 19 | 100 | 22 | 116 | 20 | 105 | 21 | 110 |
| | | | 20 | 29 | 152 | 21 | 110 | 21 | 110 | 19 | 100 | 21 | 110 |
| | | | 40 | 45 | 214 | 30 | 143 | 23 | 105 | 21 | 100 | 21 | 100 |
| | | | 60 | .. | .. | 37 | 161 | 28 | 117 | 25 | 109 | 23 | 100 |
| | | | 90 | .. | .. | 44 | 169 | 38 | 146 | 32 | 123 | 26 | 100 |
| 90 | 39 | Crank | 0 | 21 | 110 | 19 | 100 | 19 | 100 | 20 | 105 | 22 | 116 |
| | | | 20 | 30 | 150 | 21[3] | 105 | 21[3] | 105 | 20[3] | 100 | 22[3] | 110 |
| | | | 40 | 51 | 243 | 23 | 110 | 23 | 110 | 21 | 100 | 22 | 105 |
| | | | 90 | .. | .. | 35 | 146 | 29 | 121 | 25 | 104 | 24 | 100 |
| —45 | 40 | Wheel | 0 | 20 | 100 | 20 | 100 | .. | .. | 22 | 110 | 22 | 110 |
| | | | 20 | 23 | 109 | 21[3] | 114 | .. | .. | 22[3] | 100 | 22[3] | 100 |
| | | | 40 | 28 | 133 | 22 | 104 | .. | .. | 21 | 100 | 22 | 104 |
| | | | 90 | .. | .. | 28 | 122 | .. | .. | 23 | 100 | 24 | 104 |
| —45 | 40 | Crank | 0 | .. | .. | 19 | 100 | .. | .. | 19 | 100 | 20 | 105 |
| | | | 40 | .. | .. | 22 | 110 | .. | .. | 20 | 100 | 21 | 105 |
| | | | 90 | .. | .. | 27 | 123 | .. | .. | 23 | 104 | 22 | 100 |
| +45 | 42 | Wheel | 0 | 20 | 105 | 19 | 100 | .. | .. | 21 | 110 | 22 | 113 |
| | | | 20 | 23 | 110 | 21[3] | 100 | .. | .. | 21[3] | 100 | 22[3] | 105 |
| | | | 40 | 35 | 175 | 22 | 110 | .. | .. | 20 | 100 | 22 | 110 |
| | | | 90 | .. | .. | 30 | 150 | .. | .. | 26 | 100 | 26 | 100 |
| +45 | 42 | Crank | 0 | .. | .. | 19 | 100 | .. | .. | 19 | 100 | 22 | 116 |
| | | | 40 | .. | .. | 21 | 100 | .. | .. | 21 | 100 | 22 | 105 |
| | | | 90 | .. | .. | 27 | 112 | .. | .. | 23 | 100 | 25 | 108 |
| 0 | 48 | Wheel | 0 | 18 | 100 | 19 | 106 | 20 | 111 | 20 | 111 | 21 | 116 |
| | | | 20 | 23 | 115 | 21[3] | 105 | 20[3] | 100 | 20[3] | 100 | 21[3] | 105 |
| | | | 40 | 34 | 170 | 22 | 110 | 20 | 100 | 20 | 100 | 21 | 105 |
| | | | 90 | .. | .. | 34 | 142 | 29 | 121 | 24 | 100 | 25 | 104 |
| 0 | 48 | Crank | 0 | 18 | 112 | 16 | 100 | 17 | 106 | 17 | 106 | 18 | 112 |
| | | | 20 | 26 | 144 | 19[3] | 106 | 19[3] | 106 | 18[3] | 100 | 19[3] | 106 |
| | | | 40 | 43 | 226 | 21 | 110 | 21 | 110 | 19 | 100 | 21 | 110 |
| | | | 90 | .. | .. | 35 | 159 | 27 | 123 | 23 | 105 | 22 | 100 |
| 0 | 48 | Cross Bar | 0 | .. | .. | .. | .. | .. | .. | 19 | 100 | 21 | 110 |
| | | | 40 | .. | .. | .. | .. | .. | .. | 25 | 114 | 22 | 100 |
| | | | 90 | .. | .. | .. | .. | .. | .. | 26 | 113 | 23 | 100 |
| 0 | 58 | Wheel | 10 | 21 | 117 | 18 | 100 | .. | .. | 21 | 117 | 23[3] | 128 |
| | | | 20 | 25 | 131 | 19[3] | 100 | .. | .. | 21[3] | 110 | 23 | 121 |
| | | | 40 | 38 | 173 | 22 | 100 | .. | .. | 22 | 100 | 23 | 104 |
| | | | 90 | .. | .. | 32 | 123 | .. | .. | 26 | 100 | 28 | 108 |
| 0 | 58 | Crank | 10 | .. | .. | 20 | 105 | .. | .. | 19 | 100 | 22 | 116 |
| | | | 40 | .. | .. | 22 | 100 | .. | .. | 22 | 100 | 24 | 109 |
| | | | 90 | .. | .. | 36 | 144 | .. | .. | 25 | 100 | 27 | 108 |

[1] Time in thousandths of a minute; grand mean of nine operators performing under each set of conditions.
[2] Best performance at each torque = 100 per cent. Higher percentages indicate progressively poorer performances at each torque.
[3] Interpolated.

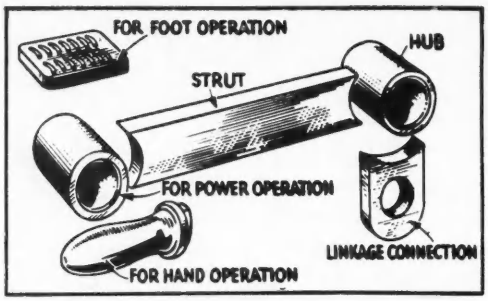



Fig. 14. **The basic elements of lever design.**

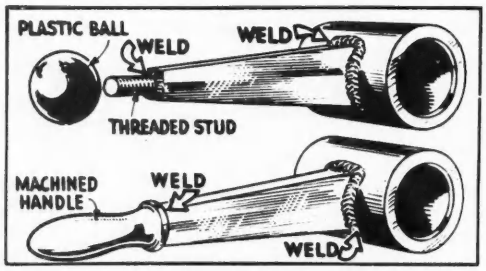



Fig. 15. **Levers for hand operation.**

been overlooked, furnish the designer with an appreciable aid for improving machine output and facilitating operation if he pays attention to facts now made known by research workers.

In this connection, a technique is worth mentioning where the part played by the operator is taken over by a

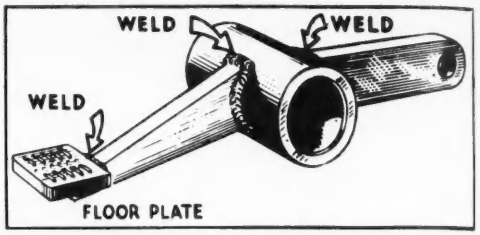



Fig. 16. **Foot-operated welded lever with linkage connection.**

" human " template[8]. This template, constructed on a 1 in. to 1 ft. scale, is used for testing designs in their initial stages, and by using appropriate symbols, a " man-machine chart " can be drawn up, by means of which shortcomings can be discovered and remedied. If the machine designer is prepared to make use of the techniques referred to, this should lead to considerably improved overall designs for most types of machines.

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## COMMUTATOR DESIGN and MANUFACTURE

(*Continued from page* 242)

Furthermore

$$\tau_k - \tau_k' = 2\,h_0 \tan(\gamma_0/2) \qquad (3)$$

and it has already been shown that

$$\Delta = 2\,h_0 \tan(\gamma_0/2) - (b_e - b_i) \qquad (4)$$

Substituting eqs. (1) and (2) in (3), we obtain

$$p_i A_i - p_e A_e = 2\,h_0 \tan(\gamma_0/2) - (b_e - b_i)$$

where

$$A_i = (b_i/E_c) + (s/E_m) \text{ and } A_e = (b_e/E_c) + (s/E_m).$$

Therefore

$$p_i A_i - p_e A_e = \Delta \qquad (II)$$

Introducing the ratio $E_c/E_w = \kappa$ in this equation, and multiplying both sides by $E_c$, we have the expression

$$E_c\Delta = p_i(b_i + \kappa s) - p_e(b_e + \kappa s) \qquad (IIa)$$

The significance of this equation will now be illustrated by a *numerical example*, based on a commutator of medium size with an outer diameter of approximately 856 mm. Let $K = 213$ bars, $b_e = 1{\cdot}1625$ cm, $b_i = 1{\cdot}021$ cm, $h_0 = 4{\cdot}8$ cm, $E_m = 0{\cdot}44 \times 10^6$ kg/cm² (phlogopite)*, $E_c = 1{\cdot}21 \times 10^6$ kg/cm²† (hard-drawn copper), $\kappa = 2{\cdot}75$, $s = 0{\cdot}10$ cm, $\tan(\gamma_0/2) = \tan(180°/213) = 0{\cdot}014750$, $b_e - b_i = 0{\cdot}1415$ cm. Then $\Delta = 0{\cdot}1416 - 0{\cdot}1415 = 0{\cdot}000\,1$ cm (from eq. (4)). The value of $p_e$ should be chosen as low as possible, that is, just sufficient to give a fully closed running surface. Let, therefore, $p_e = 2{\cdot}0$ kg/cm². Equation (IIa) then becomes

$$p_i(1{\cdot}021 + 0{\cdot}275) - 2(1{\cdot}1625 + 0{\cdot}275) = 0{\cdot}0001 \times 1{\cdot}21 \times 10^6 = 121, \text{ and } p_i = 95{\cdot}58 \text{ kg/cm}^2$$

Although this is a moderate value for the maximum flank pressure it is remarkable that such a slight excess in thickness as 1/1000th of a millimetre should be capable of producing this appreciable difference between the inner and outer pressures. It is now easy to realise what will occur if $\Delta$ is 20-30 times greater and has a " negative " value, that is, when the excess in thickness is in the outer portion of the bar, as in case (a) of Fig. 3. Whether positive or negative, a value of $\Delta$ of this magnitude makes it impossible, even with the highest tightening pressures used in practice, to close completely the two surfaces of the packs of bars and separators. To achieve this it is necessary to apply forces which will generate permanent deformations until the bars and separators are in contact over the entire flank width. For this purpose, the commutator is usually subjected to a " seasoning " process, during which it is heated and then tightened up, the cycle being generally repeated several times.

The order of magnitude of the stresses produced by the tightening process in order to eliminate the taper angle inaccuracy can be assessed from the following *example*. The same commutator as previously will be considered, assuming, however, that the bars sup-

(*Continued on page* 258)

*Value calculated from measured results published by : ADAMS, L. H., & E. D. WILLIAMSON : On the compressibility of minerals and rocks at high pressure. *J. Franklin Institute*, Vol. 195, 1923, p. 475.

†Arbitrarily chosen in the range $1{\cdot}15$-$1{\cdot}25 \times 10^6$ kg/cm².

# CLASSIFIED ABSTRACTS

*Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.*

## ELECTRIC FURNACES

### An Induction Stirrer for Arc Furnaces

By L. DREYFUS. (From *Asea Journal, Sweden*, Vol. 23, No. 3-4, March/April, 1950, pp. 46-54, 10 illustrations.)

ELECTRODYNAMIC forces are a phenomenon common to all electric furnaces in which the current is conducted through the melt, but in the case of the arc furnace, these forces are very slight. Although conditions are more favourable in furnaces provided with a bottom electrode, theoretical considerations indicate that an adequately powerful stirring motion can only be induced by means of external stirring coils. The most satisfactory solution of the stirring problem is afforded by the use of multi-phase, overlapping coils, mounted beneath a furnace bottom plate of non-magnetic material.

The frequency should be chosen sufficiently low to avoid excessive eddy current losses in the furnace plate, but, at the same time, high enough to ensure that the motive forces generated in the bottom layer of the melt shall be able thoroughly to stir the melt in a short space of time. This stirring motion also materially assists the slagging operation.

Results obtained with the two furnaces which have so far been equipped with stirring coils have fully realized all expectations.

## IRON AND STEEL FOUNDRY PRACTICE

### New Gun Relines Cupola in One Hour

By V. E. HILIMAN. (From *The Iron Age, U.S.A.*, Vol. 165, No. 18, May 4, 1950, pp. 94-95, 1 illustration.)

IN most foundries, the cost of relining cupolas, after dumping following each 8-hr casting shift, constitutes a signincant item because the labour required is expensive and so too are the refractories required. Until recently, relining was done in the conventional way by hand application and ramming of the patches.

In such work, patches of ganister and clay mixes more than 2 in. thick are not recommended and, as patches up to 12 in. thick are often needed, bricks had to be added. Average time for relining, including chipping out slag, coke and oxide, was 29 man-hours. In seeking to reduce this cost, it was decided to experiment with a gun fed from a dry mixing device. Water, plus compressed air for atomising it, is added at the gun along with the stream of refractories, which is fed through a 2-in. hose, 60 ft long, by compressed air from the mixing device.

By using this equipment, a wet stream of refractories is made to issue from the gun at high velocity, and it is this velocity that packs or rams the refractories, as is required for a satisfactory cupola relining job. No hand ramming is required when the gun is used, but it is necessary first to chip out the areas to be patched, just as was done previously for hand ramming.

After the surface to be repaired is chipped, the gun is used to apply the necessary coating and it can be made of any desired thickness up to 10 in. or more where this is necessary to restore the surface to the desired contour. This new technique makes possible the use of the most modern design in contours and these in themselves reduce refractory costs from 20 per cent to 40 per cent.

## MACHINE DESIGN

### Cam Follower Dynamics

By D. B. MITCHELL. (From *Machine Design, U.S.A.*, Vol. 22, No. 6, June, 1950, pp. 151-154, 6 illustrations.)

A CONTROVERSY has existed for some time over which of the three commonly used cam profiles would provide the most desirable follower motion in cases where that motion is not prescribed by the requirements of the machine of which the cam is a part. The three profiles in question are curves of parabolic, harmonic and cycloidal form. A desirable follower motion is one which requires minimum time, provides smooth acceleration and deceleration of parts, and provides positive, accurately controlled motion. This motion should be produced by a cam which is inexpensive to make and which requires a minimum of maintenance.

Tests were made on all three cams at fixed speed from 20 to 170 rpm, and with follower natural frequencies of 20 to 162·5 cps. Results show clearly that the cycloidal profile has at least two obvious advantages, namely :—

(1) The peak forces produced are generally slightly lower than those produced by the other profiles.
(2) The oscillatory forces produced are much smaller in amplitude than those produced by the other profiles. This should permit higher machine speeds without excessive vibration, and should make both cams and followers wear longer in service.

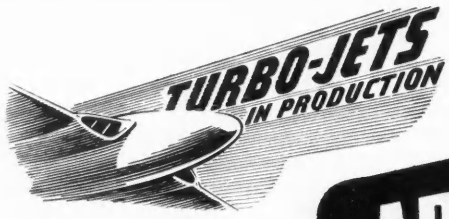
A most important point in the reduction of oscillatory forces is the construction of the follower system. This should be made as stiff as possible with as low a mass as possible. In special cases where a system having a low natural frequency must be used, damping may be introduced into the follower system itself, but never between the follower and the machine frame.

## METALLURGICAL ENGINEERING

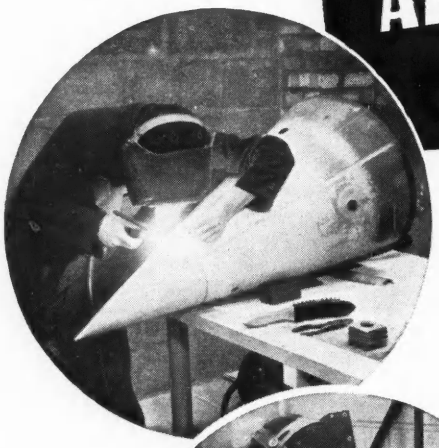
### Apparatus for Preparation of Metals with an Exactly Known Content of Impurities

By J. D. FAST. (From *Philips Technical Review, Holland*, Vol. 11, No. 8, February, 1950, pp. 241-244, 2 illustrations.)

IN order to study the influence of carbon, oxygen, nitrogen and other substances upon the properties of iron, a melting apparatus has been designed, by means of which the impurities can be added to extremely pure iron in exactly known quantities. Melting is done by means of induction heating; the melting process can be followed throughout due to the fact that the crucible is contained in a cooled glass jacket. The preparation of the purest possible iron is described. In the case of relatively large quantities (more than about 1 kg), it is found impracticable to study the influence of nitrogen separately. This influence can then only be deduced from the differences in the behaviour of iron containing oxygen or carbon, with and without nitrogen as admixture.




# ARGONARC *Welding*



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## MOTOR TRUCKS

### Analysis of a Monocoque Aluminium Semi-Trailer

By J. H. DUNN and R. L. MOORE. (From *Automotive Industries, U.S.A.*, Vol. 102, No. 12, June 15, 1950, pp. 42-44, 60-62, 4 illustrations.)

THE principles of monocoque construction are well established in some fields, particularly aircraft. While there have been many thousands of aluminium monocoque semi-trailers in operation, little work has been done to correlate design theories with actual stresses in trailer structures. Consequently, tests were conducted on a prototype model, in conjunction with a study of aluminium alloys as applied to monocoque trailer construction. A summary of the most significant measurements on the aluminium superstructure of the trailer is given in the original paper.

While the tests were valuable in determining the structural behaviour and suitability of the trailer design in question, some general conclusions can be drawn :—

(1) Performance in these tests confirmed the adequacy of the principles of monocoque design from the standpoint of major deflections and stresses in semi-trailers.

(2) The magnitude of the bending stresses and distortions produced at the side-door opening indicates the necessity of careful attention to the side-door location with respect to sections of maximum bending moment, and the need for adequate shear reinforcement.

(3) Most efficient design will take into account the fact that the highest shear stresses, and consequently the greatest tendencies towards buckling, will be developed in the lower portions of the side panels.

(4) Most efficient design will recognize also the necessity of providing side posts of greater strength and stiffness at points where major reactions are introduced.

## SURFACE TREATMENT

### Surface Preparation Values and Sand-blasting Economics

By A. J. LIEBMAN. (From *Corrosion, U.S.A.*, Vol. 6, No. 5, May, 1950, pp. 151-157, 8 illustrations.)

THIS paper aims to show how surface preparations can be dependably and economically determined beforehand, and the total performance value of coatings either increased or decreased, depending on service requirements. An outline of all suitable surface preparation methods is given although the main emphasis is on preparation by sandblasting. Metal can be sandblasted by the dry or wet process in either an open or closed system. Present limited use of proper terminology and good selective interpretation of blasting work develops costs which can range from 5 to 40 cents per sq. ft. There is a need for some fluctuation, but in many cases greater initial economy is possible if real needs are understood. Distinct practical dividing lines for blast finish classifications must be found to interpret such needs properly. Presently, it is said "blast the surface and prepare for paint application." One operator interprets this as a job which can be covered at the rate of 350 ft per hour ; and another operator at the rate of 100 fphr. Because of this ambiguous meaning, many a blast job has to be repeated.

Some sands produce a high initial breakdown. The ultimate production and surface quality depends largely on well selected sand. With present labour costs, equipment can mean the difference between success and failure on a job. The paper touches on the importance of equipment which will dependably help to reduce the overall cost in sandblasting.

## WELDING

### Notch Toughness of Single-Bead Arc-Weld Deposits with Mineral-Coated Fast-Melting Welding Rods

By W. J. KAUFMAN. (From *De Ingenieur, Holland*, Vol. 62, No. 7, February 17, 1950, pp. 9-20, 14 illustrations)

THIS article describes an investigation of the toughness at room temperature of single-bead arc-weld deposits in the (a) as welded, (b) stress-relieved, (c) normalised, and (d) normalised and stress-relieved condition. A comparison is made with the notch toughness of multi-layer welds made with welding rods of the same type and manufacture in the as-welded and stress-relieved condition. The estimation of the toughness is made with impact tests on Charpy-keyhole specimens with a 15 kg Charpy-hammer, and partially also with static notch bend tests carried out with the Hounsfield tensometer.

The welding rods are of the mineral-coated fast-melting type for down-hand work. Two makes are tested, a Dutch and an imported one. The most important conclusions are : (a) The single-bead weld material is less tough than material deposited by more layers. (b) Stress-relieving decreases the toughness of the single-bead weld material. Only with the notch-bend test on weld material deposited with the electrode of foreign origin, a small increase of toughness is stated. (c) The behaviour of single-bead welds in the static and dynamic tests is not the same. (d) The testing of the single-bead specimen at room temperature is carried out in the transition zone from ductile to brittle. (e) After normalising, the single-bead weld material gains in toughness but still remains 25-35 per cent below the non-stress-relieved multi-layer weld material. (f) Stress-relieving of the normalised specimens raises the toughness to the level of the stress-relieved multi-layer material.

## COMMUTATOR DESIGN and MANUFACTURE

(*continued from p.* 256)

plied have a thickness at the inner surface 0·00254 cm (0·001 in.) smaller than the thickness $b_i$ required. This inaccuracy is within the tolerances permitted by British Standard No. 445/1932. According to Section 5 of the latter, if a bar is placed against a vee template for checking the taper angle, the total clearance between the template and one edge of the bar should not exceed 0·001 in. on either the thick side or the thin side.

The value of $\Delta$ is then $0{\cdot}0001 - 0{\cdot}00254 = -0{\cdot}00244$ cm, or 24·4 times the value previously obtained, and $\Delta$ has a negative sign. Substituting the corresponding numerical values in eq. (IIa), and assuming that the applied forces are just sufficient to close the inner surface (so that $p_i = 0$), we have

$$-p_e\,(1{\cdot}1625 + 0{\cdot}275) = -0{\cdot}00244 \times 1{\cdot}21 \times 10^6,$$

or $p_e = 2053{\cdot}8$ kg/cm².

If the inner thickness is 0·00254 cm in excess of the nominal value, $\Delta$ is positive, and the results are

$b_i = 1{\cdot}02354$ cm $= 0{\cdot}0001 + 0{\cdot}00254 = 0{\cdot}00264$ cm ;

$p_e = 0$ (forces just sufficient to close the running surface) ;

$p_i\,(1{\cdot}02354 + 0{\cdot}275) = 0{\cdot}00264 \times 1{\cdot}21 \times 10^6$, or $p_i = 2459{\cdot}9$ kg/cm².

In both cases the stress is above the elastic limit of copper and probably even further above that of mica, for which, however, no measured values are available. This example shows therefore that even with a manufacturing tolerance of 1/40th of a millimetre (i.e. 0·001 in.), permanent deformations are created if it is required that both surfaces of the commutator be fully closed.

(*To be continued*).

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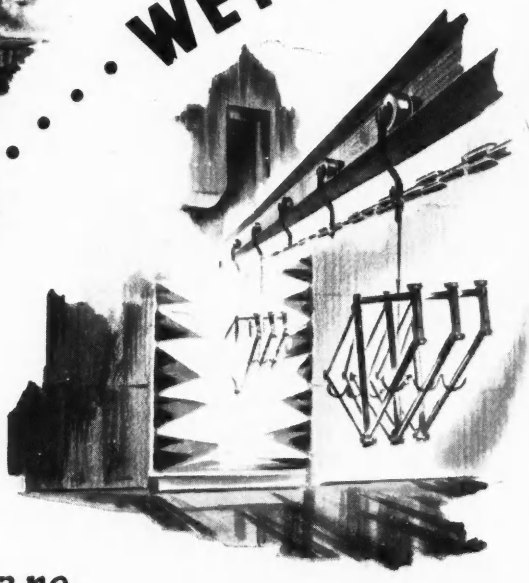

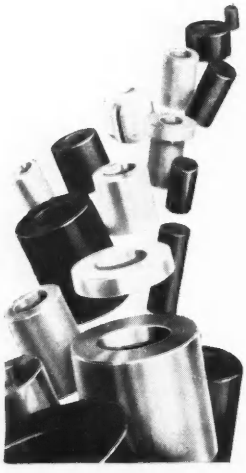

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# NEWS OF THE MONTH

## PERSONAL

**Dr. R. T. Ackroyd** has been appointed full-time lecturer in electrical engineering in the University of Sheffield.

**Sir Edward Appleton, G.B.E., K.C.B., D.Sc., F.R.S.,** Principal of Edinburgh University, and **Mr. A. S. MacLellan, B.Sc.(Glas.), M.I.N.A.,** managing director of Alexander Stephen & Sons, Ltd., Glasgow, have received the honorary degree of Doctor of Laws from the University of Glasgow.

**Major-General K. C. Appleyard, C.B.E., T.D., D.L., J.P., M.I.Mech.E., M.I.Prod.E., A.M.I.Min.E., A.I.M.E.,** has been elected President, and **Mr. Walter C. Puckey, M.I.Prod.E., F.I.I.A.,** chairman of the Council of The Institution of Production Engineers.

**Mr. W. J. Bird** has been appointed sales manager of the General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2, for the London area.

**Mr. W. R. Cook, M.Sc.,** who has been director of physical research at the Admiralty since 1947, has been appointed Chief of the Royal Naval Scientific Service.

**Mr. J. Cunningham, M.B.E., M.I.Mech.E., M.I.P.E.,** general manager of the Boiler Division, and **Mr. R. C. Shepherd,** general foundries manager, have been appointed to the Board of Ruston & Hornsby Ltd., Lincoln.

**Mr. H. R. Davenport, A.M.I.C.E., M.I.W.E.,** has been appointed waterworks engineer and manager to Bolton Corporation.

**Mr. Frank H. Dawson, C.B.E., M.C.,** has been appointed general manager of the Cunard Steam Ship Company Ltd., Cunard Building, Liverpool 3.

**Mr. J. C. Dickinson** has been appointed works manager of Brockhouse Engineering (Southport) Ltd., Crossens, Southport.

**Viscount Falmouth, M.I.Mech.E., Comp.I.E.E.,** has been re-elected President of the British Internal Combustion Engine Research Association. **Vice-Admiral(E) The Hon. D. C. Maxwell, C.B., C.B.E.,** has been elected, and **Lieut.-General Sir F. G. Wrisberg, K.B.E., C.B., Dr. S. F. Dorey, C.B.E., F.R.S., Air Commodore F. R. Banks, C.B., O.B.E., Sir Lynden Macassey, K.B.E., K.C.,** and **Major-General Clayton, C.B., C.B.E.,** have been re-elected vice-presidents. **Mr. J. Jones, M.I.Mech.E.,** of the National Gas and Oil Engine Co., Ltd, has been re-elected chairman of the Council.

**Mr. H. O. Field, O.B.E., T.D., A.C.G.I., A.M.I.C.E., A.M.I.Mech.E.,** has been appointed general manager and has joined the Board of Henry Meadows Ltd., Fallings Park, Wolverhampton.

**Mr. W. T. Gill** has been elected President of The Society of British Aircraft Constructors, 32 Saville Row, London, W.1, for 1950-51. **Mr. H. Burroughes** and **Sir Roy Dobson** have been elected vice-presidents and **Sir Frederick Handley Page** honorary treasurer.

**Mr. E. Basil Green** has been appointed managing director of Doulton & Co., Ltd., Albert Embankment, London, S.E.1.

**Mr. J. H. Lord,** an executive director of the Dunlop Rubber Co., Ltd., has been elected vice-president of the Federation of British Rubber Manufacturers' Associations.

**Mr. M. R. Neville, M.C., M.A., A.M.I.E.E.,** has been appointed manager of the Publicity Organisation of the General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2.

**Mr. R. P. Raikes, D.S.O.,** has been appointed publicity manager of Marconi's Wireless Telegraph Co., Ltd., Chelmsford.

**Mr. William S. Richards** has been elected a director of the Brightside Foundry and Engineering Co., Ltd., Sheffield.

**Mr. Selby T. Robson,** London manager of the Head Wrightson Group, has been appointed a director of Head Wrightson & Co., Ltd.

**Mr. Alfred Roebuck, M.I.Mech.E.,** has retired from the Board of Hadfields Ltd., Sheffield, at his own request, but will remain in the services of the Company as Consultant, and he will also continue to act as a director of John Baker & Bessemer Ltd., Kilnhurst, near Rotherham.

**Sir Basil R. G. Tangye, Bt., Mr. N. Rowbotham, Mr. S. Rawson, Mr. George Bryden, Mr. G. Ronald Pryor** and **Mr. F. Kershaw Lord** have been appointed to the Council of the Production Engineering Research Association of Great Britain.

**Mr. Norman Tattersall** has been appointed acting chief engineer of Leyland Motors Ltd., Leyland, Lancashire.

**Dr. John Fairfield Thompson,** President of The International Nickel Company of Canada Ltd. has been presented with an Honorary Doctor of Science Degree by General Dwight D. Eisenhower, Dean of Columbia University, New York.

**Mr. J. D. Vaughan, M.Sc., M.I.C.E., M.I.Struct.E.,** has been appointed chief engineer, and **Mr. J. Sim,** production manager, of Horseley Bridge and Thomas Piggott Ltd., Tipton, Staffs.

**Mr. James Venus, A.M.I.N.A.,** has been appointed naval architect with the Aluminium Development Association in place of **Mr. G. L. Watkins** who resigned to join another organisation.

**Mr. E. S. Waddington, F.S.E., M.Inst.W., A.M.I.E., (S.A.) Associate I.E.E.,** of the Industrial Department of Philips Electrical Limited, has been elected Vice-Chairman of the B.E.A.M.A. Arc Welding Plant Section.

**Mr. A. H. Waine, A.Met.(Sheff.), A.I.Mech.E., F.I.M.,** has been elected to the Board of Hadfields Ltd., Sheffield.

**Mr. H. Watson-Jones, M.Eng.(L'pool), M.I.Mech.E., M.I.E.E., M.I.Min.E.,** has been appointed divisional chief engineer (mechanical and electrical) to the new Durham Division of the National Coal Board.

**Mr. W. G. Weston, C.M.G.,** has been appointed general manager of the Marine Department of the Anglo-Saxon Petroleum Co., Ltd.

## BUSINESS NOTES

**Tufnol Ltd.,** Perry Barr, Birmingham 22 B., has opened a new branch office at 6 Clare Street, Bristol 1, Tel. No. 23304-5. **Mr. W. L. Tout** who has been resident engineer for Tufnol in the West country since 1945 has been appointed manager of the new branch office.

**F. J. Edwards Ltd.,** 359-361 Euston Road, London, N.W.1, have appointed **William Jacks & Co., Ltd.,** of Hamilton House, Graham Road, Bombay, as their representatives for India, Pakistan, Malaya and Burma.

**Dowty Equipment of Canada Ltd.** has completed an agreement with the **Dunlop Rim and Wheel Co., Ltd.,** for the manufacture of Dunlop Wheels and brakes and operating gear to be carried out at the Dowty Company's factory at Ajax, Toronto, Ontario, Canada. Dunlop wheels and brakes are standard on many types now in use by the Royal Canadian Air Fore and on the Canadian Avro C.102 Jet Liner and the CF.100 Jet Fighter.

**Dowty Liquid Springs for U.S.A.** The Cleveland Pneumatic Co., Cleveland, Ohio, largest manufacturers of undercarriages

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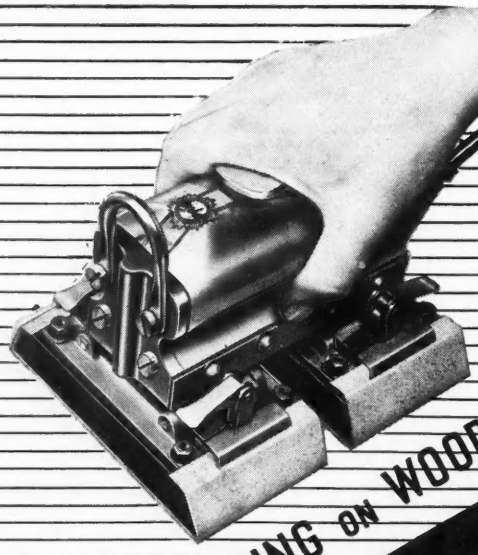

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in the U.S.A., have acquired licence and manufacturing rights of the Dowty Liquid Spring Shock Absorber for aircraft undercarriages. A shock absorber strut, designed and manufactured in Cheltenham, using pre-stressed cylinders and silicone fluids, has already been applied to the B.36 bomber at Wright Field. In Great Britain many aircraft, including the Brabazon, Hawker P.10/52, Wyvern, Canberra, and in Canada both the Avro Jet Liner and the CF.100 Fighter have been using this system of suspension.

**The Osborn Foundry & Engineering Co., Ltd.,** Sheffield, has commenced the production of American designed oil refinery equipment under a five-year agreement with the Ohio Steel Foundry Company. It is expected that between £250,000 and £500,000 will be saved in dollars annually.

**Albright & Wilson Ltd.** announce that permission has been received from the Board of Trade for the construction of a new phosphorus plant at Portishead, near Bristol. Work will begin on the 20 acre dockside site as soon as planning permission has been obtained. The output of this factory, which will cost about £1,000,000, will be in addition to existing production at Oldbury and Widnes, and it is hoped that the plant will be in production by 1953. The factory, when completed, will be the largest of its kind in the United Kingdom.

**Correction.**—The illustration in the advertisement which appeared in our June issue to feature the ETHULON TRACING FILM manufactured by Messrs. May & Baker Ltd., Dagenham, Essex, was printed inadvertently upside down. The complete stereo supplied for this advertisement has now been corrected for publication in our September issue.

## THE NEW PERKINS DIESEL WORKS

F. Perkins Ltd., of Peterborough, has invited the trade and technical press to a pre-view "At Home." Technical journalists have thus been able to gain first-hand impression of the great achievements of Mr. Frank Perkins who, in the brief span of 16 years, has built up the largest diesel engine factory in Europe from a small workshop employing a few back room boys and one mechanic.

The four employees have increased in number to over 2,400 directly employed, and the few square yards of workshop have grown to six acres of buildings in eighty-one acres of the Company's own land.

The most up-to-date factory has been designed for the production of one main standard size of diesel engine, and it is turning out more diesel horsepower than any other factory in Europe. Extensions which have already been authorized will double the size of the present factory.

Perkins diesel engines have been developed for commercial vehicles, tractors, marine propulsion units and industrial applications.

Not less than 85 per cent of the Company's output is being exported, the engines finding their way into 76 different countries.

## EXHIBITION OF INDUSTRIAL POWER

The contributions of heavy engineering to the story of British achievement will be demonstrated at the Exhibition of Industrial Power at Kelvin Hall, Glasgow, during the Festival of Britain, 1951.

The exhibition, details of which were announced by Mr. Tom Johnston, Chairman of the Festival of Britain Scottish Committee, will be one of the main exhibitions sponsored by the Festival Office.

The story will show how, by British enterprise, the power hidden in our mines and rivers has been harnessed to our daily needs. The exhibition develops, therefore, through two main sequences—one starting from coal, the other from water.

In the Power of Coal sequence the subjects covered will be mining, iron and steel, machine tools, power units from Watt to the present day, the generation and transmission of electric power, railways and shipbuilding. In the Power of Water sequence will be hydro-electricity, civil engineering and irrigation. The final section will deal with the source of power of the future—nuclear energy.

The exhibition will not only show machinery and the techniques which have gone to making it, but also the effect heavy engineering has had on our daily lives. Implicit in the story, indeed, is Britain's rise as an industrial country. The time setting, however, is the present and topical subjects, including the part now played by the research scientist, will have pride of place. The North of Scotland Hydro-Electric Scheme, for instance, will form an important display. From abroad, topical subject matter will be provided by the Nile Valley irrigation scheme by which British engineers are helping to improve the standards of living of millions of people.

New methods of display will be employed, fully supported by the best than can be shown of current British industrial production, for the provision of which the Council of Industrial Design will be responsible. The exhibition will cover 100,000 square feet—more than three times the size of "Enterprise Scotland" and bigger than "Britain Can Make It."

Mr. Basil Spence, the co-ordinating architect, has designed a spectacular entrance to the exhibition—the Hall of Power—which will be dominated by a cliff of coal bearing huge sculptured figures. The second great source of industrial power will be represented by a surging mass of water on the glazed roof of a stairway.

Pit cages will take visitors to a coal face where Scots miners will be operating the most up-to-date coal cutting machinery. For contrast, there will be a reconstruction of a coal mine of 200 years ago. Realism will be given to the descent of the mine shaft by devices which will give an illusion of a 1,000-foot descent although the drop is only one of 12 feet.

The main exhibition will have sections devoted to coal, steel, machine tools, engines, electric power, hydro-electricity, civil

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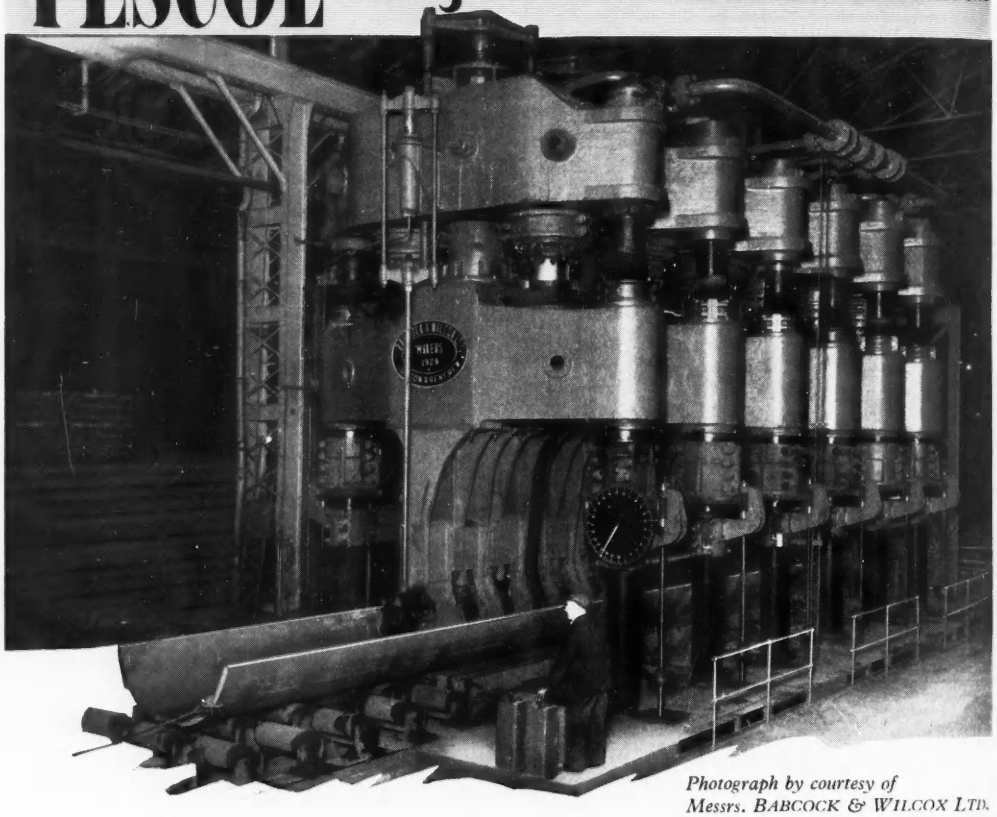

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engineering, irrigation, railways and shipbuilding. Finally, the Hall of the Future, which will be devoted to atomic energy, will show the work which is going forward in atomic energy application and research; this will be housed in a great dome inside which the night sky will be shimmering. From the floor will project a metal cone from the point of which lightning flashes will crackle up to the "sky" to symbolise the power released from the atom.

The use of the sources of energy for heavy engineering—coal and water—will be presented in two alternative routes through the exhibition. Each sequence will end in a central section where British enterprise in shipbuilding and railways will be demonstrated.

## STANDARD BRONZE BARS

In the past, bronze bars have been marketed in the "as cast" condition with a machining allowance of $\frac{1}{8}$ in. on the diameter and in the bore. When using "as cast" bars, however, certain disadvantages may be encountered. There is the danger of under-surface defects which can be found only after a certain amount of machining has taken place, and which may mean scrapping a part after a good deal of time has been spent on it. Furthermore, the removal of the "as cast" surface involves heavy tool wear, and waste metal in swarf.

With this in mind, the Glacier Metal Co., Ltd., marketed a standard range of Chill Cast Phosphor Bronze bars in the well-known 2B8 specification, machined on the outside diameter. These bars have a nominal machining allowance of ·020 in. on the outside diameter, leaving only a ·010 in. cut for finishing by the user. Thus, by the use of these bars, less metal is wasted, and there is a considerable saving on tool wear and machining time.

As a further step, the Company has now revised this programme to incorporate a standard range of 153 sizes of bars in the 2B8 Chill Cast Phosphor Bronze specification, and also two lead bronze specifications, all machined both on the outside diameter and in the bore.

Only ·010 in. cuts on the outside diameter, and ·015 in. cuts in the bore are needed for finishing, and by this means there is an even greater saving in metal, tool wear and machining time. An interesting comparison can be made between the amount of metal used for the same work by buying Glacier Standard Bronze bars, as opposed to "as cast" bars. Assuming a user wants to make 100 bushes $1\frac{3}{4}$ in. o/d × $1\frac{1}{4}$ in i/d × 2 in. long, he buys 17 bars of the same nominal dimensions which weigh only 91 lbs. as against the purchase of 17 bars $1\frac{7}{8}$ in o/d × $1\frac{1}{4}$ i/d weighing 125 lbs. In other words, on 100 bushes he saves 34 lbs. or 27 per cent metal.

Three specifications have been selected to cover the widest possible range of engineering requirements under various operating conditions. The bars are all supplied in 13 in. lengths, cored bars being available with outside diameter from 1 in. to 6 in., and solid bars with outside diameters from $\frac{5}{8}$ in. to 6 in.

A leaflet giving details of the various specifications and a size chart can be obtained on request from the Glacier Metal Co., Ltd., Alperton, Wembley, Middlesex. A price list is also available.

**Northern Ireland's Industrial Possibilities to be Explored by North American Firms.** As a result of the Northern Ireland Prime Minister's recent visit to the United States and Canada, some American and Canadian firms propose to send representatives to Northern Ireland to explore industrial possibilities on the spot. This information was given in the Northern Ireland Senate by Sir Roland Nugent, Leader of the House.

## BRITISH STANDARDS

*(Copies of British Standards may be obtained from the British Standards Institution, 24 Victoria Street, London, S.W.1.)*

### EXTERNAL MICROMETERS. (B.S. 870 : 1950)

The present revision represents an extension of the previous standard to cover micrometers of 0 to $\frac{1}{2}$ in. and from 12 in. to 24 in., with their corresponding metric equivalents, and also provides for micrometers with interchangeable anvils and various measuring ranges up to 24 in. or 600 mm.

The Standard includes requirements for material, design of frame, micrometer screw, spindle, thimble and barrel, adjustments, measuring faces, accuracy, packing and marking. Requirements are also specified for the material, general design and accuracy of setting gauges. Recommended methods of testing micrometers are given in an Appendix. Price 2/6.

### DIMENSIONS OF SCREENED MAGNETOS (G, K AND M TYPES) (B.S. 1620 : 1950)

The standard lays down dimensions for large and small magnetos for small single-cylinder and twin-cylinder engines and also for small magnetos for multi-cylinder engines. It also includes dimensions for keyways and tapers, and all the necessary tolerances which affect interchangeability. Gauges and tapers are included in appendices. Price 2/6.

### TWIST DRILLS AND COMBINED DRILL AND COUNTERSINK (CENTRE DRILLS). (B.S. 328 : 1950)

Both subjects are now combined in the revised edition of B.S. 328. The section dealing with twist drills has been amended and extended special attention having been given to the nomenclature and definitions of drill parts, as a need for this has long been apparent. The testing requirements have been brought up to date and the penetration capabilities of the drills modernized and extended.

An important innovation in the specification is the emphasis of "preferred sizes" and the quotation of alternatives in the tables covering the drill gauge and letter sizes of twist drills.

The section dealing with combined drills and countersinks (centre drills) has been presented in a manner similar to that of twist drills, and a complete range of definitions has been included together with tables giving manufacturing limits of tolerances. This section covers the provisions of B.S. 985 : 1941, which is accordingly superseded.

The dimensions of self drive holding tapers are mentioned in an Appendix and are quoted from a British Standard which is in course of preparation. Price 6/–.

### SIMPLE BEND TEST. (B.S. 1639 : 1950)

Although the simple bend test is widely used to give a ready qualitative assessment of the ductility of a metal, it is not generally appreciated that certain features of the test, probably because of its simplicity, have to be given due consideration when the precise form of the test is being decided, or when the value of the test is being assessed. It is hoped that these notes will be of assistance in this respect.

The publication is complementary to the bend test clauses of B.S. 485—"Tests on thin metal sheet and strip (not exceeding 0·128 in. (10 S.W.G.) in thickness)", but it is recommended that the provisions of that standard should be followed when testing thin metal sheet and strip. It does not, however, refer to composite or welded metals. Price 2/–.

## ANNUAL GENERAL MEETING

The Annual General Meeting of the B.S.I. was held on July 11th, 1950. Sir William Larke presided.

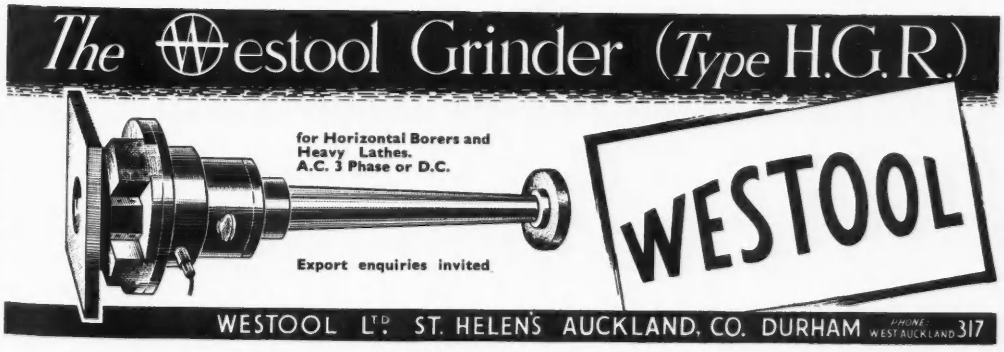
The Rt. Hon. Sir John Anderson, P.C., G.C.B., F.R.S. was elected President for the coming year.

Mr. Roger Duncalfe, Chairman of the General Council, in presenting the Annual Report, explained that the work had expanded during the year in all sections, both nationally and internationally. The B.S.I. had distributed nearly three quarters of a million copies of British Standards, many of them volumes of considerable size. The B.S.I. had participated in a number of exhibitions, and the Library and Information Service had developed substantially. The Library now holds copies of about 43,000 oversea standards.

## BOOKS

**Stetige Regelvorgänge (Continuous Control Processes).** By Winifried Oppelt. 144 pp. Publishers: Wissenschaftliche Verlagsanstalt K.G., Hannover, and Wolfenbütteler Verlagsanstalt, G.m.b.H., Wolfenbüttel.

This book provides a systematic treatment of automatic control processes on the theoretical principles set out by the author in his previous book, entitled "Fundamentals of automatic control"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(Grundgesetze der Regelung). The first part gives the characteristics of the various basic types of control systems, with the linear differential equation and a schematic diagram for each mechanism considered, as well as the corresponding transfer function loci and transient response curves. The stability conditions of each system are also considered. In the second part the treatment is extended to multiple control systems, and further sections deal with the synthesis of servomechanisms and the use of models for the investigation and testing of automatic control devices. The book is profusely illustrated and lays considerable emphasis on practical applications.

**L'écoulement en Conduites des Liquides, Gaz et Vapeurs (Flow in Ducts of Liquids, Gases and Vapours).** By A. Schlag. 245 pp., 2nd edition. Price: French francs 850. Publishers: Dunod, Paris.

This book is essentially a reference book for hydraulic engineers. After a brief survey of the fundamental equations, it gives an analysis of viscous flow, comparing quantities in engineering units with the corresponding quantities in absolute c.g.s. units. This is followed by a discussion of the principle of similarity. Particular attention is then given to the pressure losses in pipes under laminar or turbulent flow conditions, and the various formulae and coefficients for the determination of frictional losses are given for ducts of various materials, sizes and cross-sections. Branched ducts and throttling losses are also considered. The use and design of orifices, venturi meters and other flow meter arrangements is then described, and a brief treatment of pulsating flow is included. This book contains a considerable amount of numerical data in tabular form, and its recommendations are based on Belgian, British, French and German specifications. An extensive bibliography with 221 references completes this work.

**Hydraulique Générale et Mécanique des Fluides (Hydraulics and Fluid Mechanics).** By A. Schlag. 221 pp. Price: French francs 1400. Publishers: Dunod, Paris.

This book is based on lectures on theoretical hydrodynamics given by the author at Liège University. It gives the derivation of the fundamental equations of hydrostatics and hydrodynamics, and deals with streamline flow by using real variables for potential functions and velocities. Viscous flow is treated with the aid of the Navier-Stokes equations. The various formulae for pressure head losses and similarity calculations are derived and illustrated by applications to particular cases. The flow through ducts with sudden changes in cross section is also treated, and a method of successive approximations is given for the analysis of duct networks. Consideration is also given to open channels, underground ducts, and channel beds of various cross sections. Rate of flow measurement, cavitation, and water hammer, are also among the subjects treated. This volume is the theoretical complement of the book "Flow in Ducts of Liquids, Gases and Vapours," by the same author, which is also reviewed in this issue.

**Atomics.** By Eidinoff and Ruchlis. 248 pp. Price 10/6. Publishers: George G. Harrap & Co., Ltd., 182 High Holborn, London, W.C.1.

The need for popular, non-technical books on the subject of atomics which commands the interest of most but is conceivable to comparatively few, has been urgent and important. This book explains the fundamentals of atomics to non-technical readers who are thus enabled to comprehend the basic principles behind the development of atomic energy.

**Pocket Encyclopedia of Atomic Energy.** By Frank Gaynor. 204 pp. Price $7.50. Publishers: Philosophical Library, 15 East 40th Street, New York 16, N.Y.

Whilst this book lays no claim to be complete and comprehensive, it offers an extremely useful collection of brief definitions and explanations of the terms used in the science of nucleonics. Biographical sketches of outstanding workers have been included. Another supplementary feature of the book is the listing of German equivalents of a great many of the topics of the book.

**Mechanics of Flight.** By A. C. Kermode. Vol. I. 370 pp. 185 figures. Price 18/-. Publishers: Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2.

This valuable book is intended for students engaged in the various branches of applied aeronautics. It is the sixth edition, brought up-to-date to include the principles of jet and rocket propulsion.

**Modern Welding Technique.** By E. T. Gill and Eric N. Simons. 276 pp. 88 figures. Price 21/-. Publishers: Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2.

Written in excellent style, this brief but fairly comprehensive book on forge, resistance and fusion welding will serve to students and practical engineers alike as a welcome book of study and reference on the subject.

**The Nickel Bulletin,** Vol. 23, No. 5, contains a number of abstracts of important papers dealing with aspects of industrial finishing.

Some idea of the range of information presented may be seen from the following selection of subjects:—

> The high speed deposition of nickel at high density; The properties and uses of hard nickel plating; The preparation of aluminium for direct plating; The stripping of nickel electrodeposits; The porosity of electrodeposited metals; The nickel-dip treatment for enamelling, etc.

In addition, this issue contains an interesting article on acicular cast iron in textile machinery.

Copies of the *Bulletin* may be obtained, free of charge, from The Mond Nickel Co., Ltd., Sunderland House, Curzon Street, London, W.1.

## CATALOGUES

**Tangye Perfected Industrial Heater.** Tangyes Ltd., Cornwall Works, Smethwick, Birmingham, has just published an illustrated 22-page brochure which contains prices and full particulars concerning the Tangye industrial heaters. Details of spare parts are also included.

**The Birmingham & Blackburn Construction Co., Ltd.,** Bordesley Green, Birmingham, and Harley Street, Blackburn, has published under the title "The Work We Do" a well designed 24-page booklet which indicates the large variety of products on which this progressive firm of heating and ventilating engineers, steel fabricators and sheet metal workers is employed. Illustrations and descriptions reproduced in the booklet include heating, ventilating and air conditioning installations, sheet metal work and constructional steelwork, portable dust collectors, heat insulation and pipe work and various special equipment.

**For Melting Cast Iron** is the title of a leaflet just issued by The Morgan Crucible Co., Ltd., Battersea Church Road, London, S.W.11, to illustrate the Morgan crucible furnace for melting cast iron in small quantities. The leaflet is illustrated and contains full specifications.

## EUROPE'S LARGEST BROACH FACTORY

The Lapointe Machine Tool Co., Ltd., have recently occupied their new premises at Bushey, on the Watford By-Pass. This is the largest and most-up-to-date factory in Europe to be devoted solely to the manufacture of broaches and broaching machines.

The new building, claimed to be the most modern of its kind in Europe, incorporates a number of architectural features of advanced design and, except for that of the Parent company in Hudson, U.S.A., is the largest in the world to be devoted solely to the manufacture of broaches and broaching machines. Before building commenced, an accurate large-scale model, with removable roof was made, as well as a scale floor model showing the position of every machine and worker in the main production department. These proved invaluable, and enabled many minor alterations to be made before building commenced. The factory is now completed with the exception of the offices which will be added as soon as the necessary permits can be obtained.

## BRITISH PLASTICS EXHIBITION AND CONVENTION, 1951

The British Plastics Exhibition and Convention will be held from June 6 to 16, 1951, in the National Hall, Olympia, London. The exhibitors will be British and Commonwealth firms who produce, mould or fabricate plastics materials or supply raw materials or equipment to the plastics industry.

The Convention, which will run concurrently with the Exhibition, is being organised by a committee on which are represented the British Plastics Federation, the Plastics Institute and the Plastics and Polymer Group of the Society of Chemical Industry.


# Classified Advertisements.

*The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box number advertisements 1s. extra. Instructions together with remittance must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.*

## SITUATIONS WANTED

**LADY (36), single, seeks post as Secretary or Accountant. Used to all duties of Engineers' Office.—Box No. C. 71.**

**SECRETARY (female) seeking post. Experience in Technical, Works, Company, etc. Good education, single.—Box No. C. 72.**

## WANTED

**BACK ISSUES OF THE ENGINEERS' DIGEST Wanted.** Copies of the February, 1949, issue at 3/6 per copy. Double the original price, 9/- per copy offered for copies of the August, 1940, issue.—Send copies to the SUBSCRIPTION DEPARTMENT, "THE ENGINEERS' DIGEST," 120 Wigmore Street, London, W.1.

## WORK WANTED

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## FOR SALE

**NISSEN TYPE HUTS, ex-Government stock,** reconditioned and supplied ready for erection. All sizes in 6 ft. multiples. 36 ft. by 16 ft., £65 & £54; 24 ft. by 16 ft., £46 & £38; 72 ft. by 16 ft., £122 & £97; delivered U.K. Plasterboard huts and other buildings. Some 24 ft. span Nissens.—Write, call or telephone, **Universal Supplies (Belvedere) Ltd.,** Dept. 50, Crabtree Manorway, Belvedere, Kent. Telephone No. ERITH 2948.

# THE BLUE PAGES

## A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

### ● *NEW METHOD OF BOILER CLEANING*

American power plant engineers have found that inhibited phosphoric acid will remove rust and mill scale from new boilers, and water-formed insoluble deposits from boilers in service, without the limitations and adverse effects associated with inhibited hydrochloric acid. The principal advantages of phosphoric acid is reported to be the feature that it can be boiled in the unit by direct firing of the boiler with negligible attack of the metal. In addition to the beneficial washing action, the resultant natural circulation promotes distribution of the acid throughout the boiler and transports the acid to zones at the top of the boiler which otherwise could only be reached by resorting to re-circulation with an elaborate system of internal baffling. Phosphoric acid is extremely stable at temperatures well above the boiling point of the solution required, and therefore it does not produce any corrosive or noxious fumes. A five per cent inhibited acid solution boiling at atmospheric pressure was found to give good deposit removal, and negligible attack of metal was observed. Moreover, this method produced a surface resistant to subsequent rusting.

### ● *SONIC TESTING OF ABRASIVE WHEELS*

An important characteristic of abrasive wheels is that known as the " grade " or hardness. This is a measure of the tenacity with which the individual particles of abrasive are bonded together, and hence of the performance of the grinding wheel. There are several methods by which wheel grades can be determined by the wheel manufacturer. The latest of these methods, just announced, involves rapid measurement of the frequency of resonant vibration of the grinding wheel. This method thus represents a highly refined version of the old practice of tapping a suspended grinding wheel with a hammer and listening to the pitch and quality of the resulting musical tone. In the new testing device, the place of the hammer is taken by a vibrating stylus which is driven by a calibrated variable frequency generator. A dial controlling the output frequency of the generator is manually rotated until a cathode-ray tube shows a characteristic pattern associated with resonance conditions. It need hardly be said that this is a non-destructive test which produces no visible markings on the wheel. This method will also allow detection of certain types of flaws, and by simple modifications the sensitivity of the apparatus may be increased to indicate any existing inhomogeneity of the abrasive material.

### ● *MAGNETIC INDICATION OF METAL FATIGUE*

In spite of the important advances made in recent years in knowledge of the metallic structure, metallurgists have not yet succeeded in rendering a satisfactory explanation of the nature and mechanism of internal processes which lead to the failure of a material by fatigue. A survey of existing literature on the subject shows that proposals to assess metal fatigue from attendant changes in the magnetic properties have been made a number of times, without, however, leading to definite and convincing conclusions. What is probably the latest attempt on record was recently made in Germany, where test bars of 0·4 per cent carbon steel were subjected to a fatigue test of the Woehler type. During the test the pieces were magnetised by a surrounding field coil supplied with direct current, and the induction was periodically ascertained by the use of a ballistic galvanometer connected to a special coil placed inside the field coil. The test records show that changes in the magnetic properties of the material subjected to fatique test are noticeable, but no information concerning the internal processes causing fatigue failure could be derived. It is suggested that the choice of direct current magnetisation was unfortunate, and that future investigations involving the use of alternating current fields might prove more fruitful.

### ● *PRODUCTION OF RIBBED STEEL PANELS*

Recent investigations into the possibility of constructing highly compact heat exchangers with the use of finned or corrugated surfaces have shown that this type may well become very important in various applications, particularly in gas turbine plant. For reasons of simplicity of manufacture and low first cost, the availability of sheet steel with integral closely spaced fins appears, therefore, to be most desirable, and this applies no less to the field of aircraft construction, where rib-reinforced sheet of integral design

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would prove highly useful. It is interesting to note that one manufacturer is suggesting a process of rolling such panels, the proposal being based on actual experience acquired in the production of hollow steel propeller blades. In the method suggested, a flat steel blank would first be pre-forged in a press to gather material into short thick ribs. These rib sections could then be shaped into ribs of required thickness and length in a special two-roll contour mill, the final shaping being done in a draw mill. By using this principle in conjunction with a post-forging operation, the manufacturers concerned have succeeded in producing a rib height of approximately eight times the rib thickness in steel, and the production, without post-forging, of ribs with a height four times the rib thickness is confidently predicted.

### ● *NEW HAMMER-EFFECT ENAMEL*

A new one-coat hammer-effect finish which may be sprayed on metal parts at the same pressure as ordinary enamels has been perfected by an American firm, it is reported. The manufacturers state that in the development of the new finish, special account was taken of complaints by users to the effect that finishes previously available varied with the technique used by different sprayers. With the new enamel, when sprayed at standard enamel pressure, a hammer-effect with a smooth lustrous appearance is said to be immediately produced. Excellent results are claimed for tests made with the spraying of metal parts for oil burners, refrigeration equipment, sanitary containers, and similar equipment. The new enamel is manufactured in a full range of colours and can be supplied either as a bake or as an air-drying finish. Baking time is 20 minutes at 300° F in a gas oven, or eight minutes under infra-red radiation. The air-drying variety is dust-free within a few minutes and can be handled within an hour. It will dry hard overnight.

### ● *PERMANENT MAGNET-TYPE HIGH-TENSION DIRECT CURRENT GENERATORS*

In magneto-type or inductor-type alternators of conventional design, the permanent magnets providing the magnetic field were originally made in the form of stationary horseshoe magnets, and the armature constructed of soft iron constituted the revolving member. With the advent of magnetic materials of high retentivity, such as Alnico and similar alloys, the permanent magnet system could be made to form the rotor, the stationary armature being made of stacked iron stampings. Where high-tension direct current is required for carrying out electrical measurements, the latter type is particularly suitable, as the required commutation can be carried out without having recourse to mechanical commutation involving the use of brushes. In addition, the stationary coils are more easily built for high voltage. In a design recently placed on the market, the alternator is combined with full-wave bridge-type rectification, and a condenser of suitable capacitance is provided, which, in the case of insulation resistance measurement with direct current, ensures a direct current voltage supply of high constancy. Units of the design referred to are constructed for voltages of 5,000 and 2,500 V.

### ● *AUTOMATIC NON-DESTRUCTIVE SORTING DEVICE FOR METAL PARTS*

Recent years have witnessed the development of a number of non-destructive testing devices for the sorting of metal parts according to whether or not they comply with specified standards regarding composition, hardness, case depth, magnetic properties, etc. For the purpose of production sorting, automatic units with sorting speeds as high as 300 pieces per minute are now being offered. One particular sorting device utilises the principle that a metal core introduced into a high-frequency field established in a test coil will cause energy losses in this field. These core losses occurring in the field of the test coil, due to characteristics of the piece under test, decrease the output of an oscillator which is viewed on the screen of a cathode-ray tube. The pattern appearing on the screen can then be correlated with the metallurgical characteristics of the test piece. A reading is taken on a predetermined standard piece having known and specified characteristics. Any metallurgical differences existing between the standard piece and the piece under test will then be visible on the screen. This method can be applied to both magnetic and non-magnetic metallic materials, the operating frequency being chosen accordingly.

### ● *BUILDING-UP WORN PARTS BY WELDING*

The repair of worn or corroded steel surfaces of machinery parts by " building-up " or " pad " welding has proved highly successful in many instances. It is not, however, generally known that indiscriminate employment of this method may have serious consequences. A survey of this repair technique published by a large industrial insurance concern points out that building-up by welding of worn surfaces is nearly always acceptable in cases where the stress loading of the part concerned is predominantly of a static character, or where compression stresses are mainly involved. Thus, outstanding successes are recorded in the repair of cavitation and corrosion damage as affecting ship propellers, water turbine wheels, pump impellers, etc. In contrast, repairs by this method of shafting and similar parts subjected to stress reversal have frequently led to complete breakdown by fatigue

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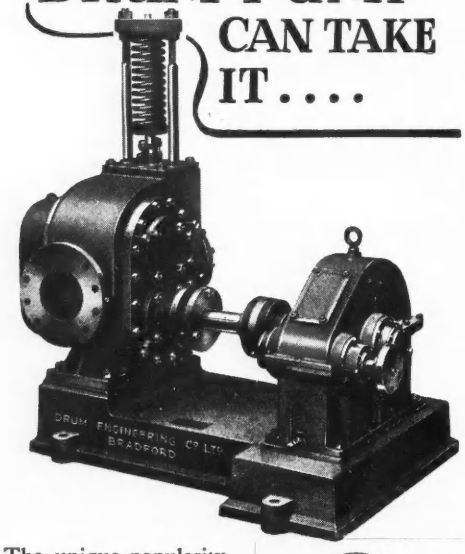


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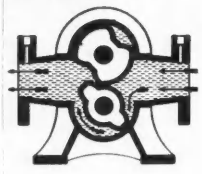

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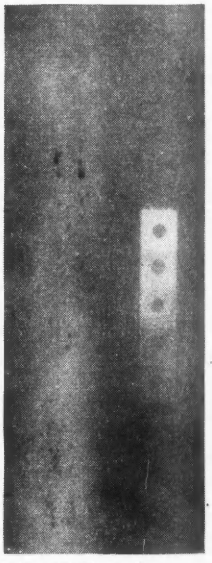

ILFORD Industrial X-ray film Type "C" is a relatively slow, fine-grained, high-contrast film which was introduced specifically for the radiography of magnesium and aluminium castings. It is also recommended, with ILFORD Lead Screens, for the radiography of steel welds up to 1" thick when 220 or 250 kVp apparatus is available. In addition, it will be found extremely useful for work with 1 or 2 million-volt equipment for which its fine grain and high contrast make it particularly suitable.

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failure. Investigations have shown that with present-day welding technique it is not possible to build up a worn surface without producing residual stresses and also a certain notch effect, the latter being due to the nature of the deposition process. It is the presence of these two disturbing phenomena which in a considerable number of cases have been found to be responsible for fatigue failure after a comparatively short time of operation. Nor can the loss in fatigue strength caused by residual stresses be recovered by stress-relieving heat treatment of the weld, and even normalising has proved to be of no avail.

### ● *WIRE BALL BEARINGS*

In the wire ball bearing which was developed in Germany by the Carl Zeiss concern some time before the war, the ball races are formed by cast steel wire of 450-500 Brinell hardness pressed into circular seats and rolled-in under heavy pressure, so that a highly polished ball track is formed. No subsequent hardening of the ball races is required. The width of the track produced by the rolling-in process will depend upon the pressure applied; and within certain limits the width of the track can, therefore, be chosen in accordance with operating conditions. Contrary to expectations, the small gap remaining between abutting ends of the circular wire does not affect quietness of operation of the bearing, especially as the abutting ends of the individual rings are mutually staggered. That such gaps do not affect bearing quality is also known from the satisfactory operation of split ball bearings of conventional design. Wire ring ball bearings are not intended to replace the ordinary standard type ball bearing, but prove most useful in cases where bearings of unusually large diameters are required, for which standard bearings are not available or would prove too costly. Where bearing loads exceed the safe working load of a single wire ring, double rings can be employed, each ring being located in a groove provided for this purpose. Bearings with diameters as large as 10 ft have been built in this way with a static load-carrying capacity of 110 tons, the ball diameter being 2 inches. A special device has to be used to roll-in the wire under the heavy pressure required.

### ● *BRIGHT FINISHING OF ALUMINIUM*

For the production of a bright surface finish on aluminium, a number of methods, electrolytic and chemical, are available, but most of them are inapplicable to mass production because they are either to complicated or too costly. Two Austrian research workers now claim to have developed a purely chemical method applicable to aluminium and wrought aluminium alloys, in which a bright finish is produced by immersing the piece in a special solution of undisclosed composition, kept at a temperature of 90 to 105° C. Process times are stated to range from 10 to 60 seconds. The finish is said to be mirror-like, but of the diffuse type. Perfect mirror finish can be produced by this method only on high-purity aluminium of 99·99 per cent purity. It is further reported that the surface produced is especially suitable for subsequent anodising treatment. The process is claimed not to require degreasing or cleaning of the surface prior to processing. A modification of the process consists in the use of an electrolytic bath treatment, which has the additional advantage of requiring bath temperatures of only 30 to 40° C. Moreover, surface appearance is further improved and the finish is more durable. Process time in this case is given as 2 to 5 minutes.

### ● *APPLICATION OF ELECTROSTRICTIVE EFFECT TO GAS ANALYSIS*

Physicists have known for some time past that non-uniform electric fields are capable of exerting by electrostriction a marked effect upon heat transfer in gases, but it is only recently that a scientific report on the analytical treatment—both qualitative and quantitative—of this interesting phenomenon has been published. This information provides basic data for the utilisation of this phenomenon for measuring the purity of gases by relatively simple means. In this method, the gas to be investigated is subjected to an inhomogeneous electric field producing local pressure differences in the gas, which, by setting up circulatory movements in the gas, increase the rate of conduction heat transfer by the gas. This effect is present in all gaseous media and is reported to be particularly marked with dipolar molecules. That this effect takes place on a considerable scale can be gauged from the fact that in certain cases a doubling of the rate of heat loss from a heated body surrounded by the gas can be obtained.

### ● *SPRAY DRYER PROGRESS*

The simplicity and efficacy of the spray drying process has led to its widespread employment in the food processing and chemical industries. One of the outstanding characteristics of the process is the extreme rapidity with which the liquid product is transformed into a dry powder, and this is a factor of vital importance in many applications. The principal element of a spray dryer is obviously the atomiser, and a great number of various types and designs has been developed and proposed in the course of development of the process. Mechanical atomisers are based upon the centrifugal principle, and in order to obtain the desired effect, the revolving parts must be operated at extremely high speeds of the order of 15,000 rpm. In the stationary type of atomiser, the atomising action is produced by a moving air stream or sheets of air

# Take a barge . . .

The entire deckhouse of the "Marbury" is built of aluminium alloy, 'Kynal' M.39/2, fully heat-treated, manufactured by the Metals Division of I.C.I. The saving in weight enables the barge to carry a greater pay-load.

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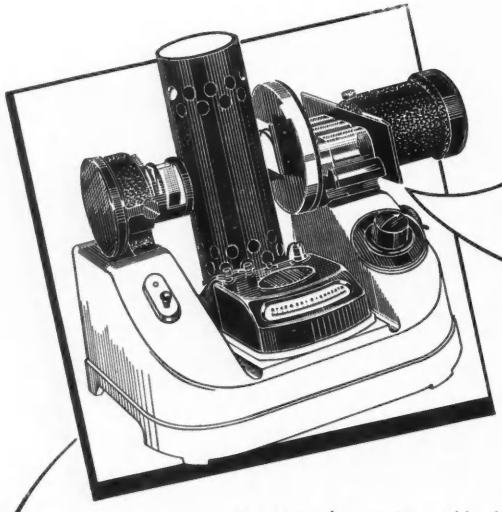

## SCIENTIFIC CONTROL

B BRITISH TO THE CORE

One of the latest known methods of metallurgical analysis, the PHOTOELECTRIC ABSORPTIOMETER is in regular use at Brymill Laboratories. By this means, light is transmitted through coloured solution: this is converted to electrical energy, and the percentage of any one element is quickly determined without separation. Just one example of the highly scientific tests that are made to ensure the impeccable standard of

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issuing at high speed from a single nozzle or a number of nozzles. One manufacturer has now developed a composite-nozzle type of atomiser, in which a central air jet is surrounded by a second air jet of peripheral annular contour, so that the liquid to be evaporated is engaged on two sides by air streams. This arrangement is claimed to have a beneficial influence upon particle size. Moreover, it permits of obtaining a required range of particle sizes by mere adjustment of the pressure of the atomising air, which represents a small percentage of the total air requirements of the drying process.

### ● *NEW AIR FILTER*

A new filter which, for the first time, makes it possible to maintain completely dust-free conditions in industrial operations at reasonable cost, was described at the recent U.S. Technical Conference on Air Pollution, held in Washington, D.C. These filters were developed by a prominent American firm of industrial consultants for the Atomic Energy Commission, which employs the filters for catching radioactive dusts. These filters are not yet available for general use, but it is understood that arrangements for their commercial manufacture are under way. The new filter should prove particularly useful in industrial plants processing photographic films or manufacturing precision devices and related equipment. They may possibly also find favour in private homes, especially those of sufferers from hay fever. It is stated that of the 20,000 particles which might be contained in one cubic inch of ordinary atmospheric air, good conventional air-filtering devices will pass 1,000 to 3,000 particles, whereas the new filter unit on the average will let by only a single particle. Spores and bacteria are retained by the filter, making the air almost sterile, it is claimed. The filtering medium is a special soft and felt-like paper containing submicroscopic asbestos fibres, which force the air to take such tortuous paths that essentially all the particles become entangled in the fibres. Large sheets of this paper are folded, collapsed in concertina fashion, and fitted in wooden frames. Single filter units can be built to handle 1,000 cu ft of air per minute at pressures well within the capacity of ordinary blowers.

### ● *CREEP OF STEEL AT ROOM TEMPERATURE*

Significant information on the fact that creep in steels under stress is not confined to high temperature ranges but may occur even at room temperature is contained in the report of an investigation of the creep properties of six steels with carbon percentages ranging from 0·08 to 0·48 per cent. An especially noteworthy feature of this investigation is that the influence of prior heat treatment was also ascertained, specimens of each steel being tested after normalizing and quenching in water from various temperatures, and, in the case of the highest carbon material, after quenching in oil and tempering at various temperatures. Furthermore, specimens were subjected, prior to the test, to a specified amount of cold work, and tested either immediately or after natural and artificial ageing respectively. From this investigation it is deduced that the characteristic creep behaviour of a steel at room temperature can be determined in a short-time test of 100 hours' duration. The creep limit suggested is the stress producing a permanent elongation of not more than 0·005 per cent in 100 hours. In the case of steels in which creep completely ceases before completion of the 100-hour test, the creep limit is defined as the stress producing no more than 0·01 per cent deformation during the period of creep. The report from which this information was obtained points out that carbon and nitrogen represent creep-inhibiting constituents.

### ● *PRODUCER GAS AS GAS TURBINE FUEL*

It is known that the problem of gas turbine operation on producer gas is under investigation in various countries. A report from the U.S.A. states that an overfired bituminous coal gas producer can be used as a source of fuel supply for this purpose, with rates of coal gasification running as high as 100 to 200 pounds of coal per hour per square foot of grate area. The carry-over of solid carbonaceous material in the gas at these rates of generation and at pressures approximating to six atmospheres, while not excessive, will call for the employment of separating equipment. Preliminary tests were conducted on a small-scale gas producer with both coke and various grades of bituminous coal. The response of the producer to rapid load changes was found to be satisfactory. While the air rate must change substantially in synchronism with the load, coal feed and ash removal control can be permitted to show time lags in the order of minutes and control requirements are therefore simplified. Tests have not yet been run to determine sufficiently the features required to avoid tar condensation and plugging due to mixtures of tars and solids. It is, however, expected that the producer temperature can be maintained high enough to keep the tar in a dry vapour form without sacrificing flexibility. The employment of gasification under pressure will make it necessary to provide coal and ash-handling mechanisms with the necessary pressure locks.

***For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.***

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